(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
29 November 2001 (29.11.2001)

PCT

(10) International Publication Number
WO 01/89567 A1

(51) International Patent Classification[7]: A61K 39/395, C07K 16/28

(21) International Application Number: PCT/US01/16364

(22) International Filing Date: 22 May 2001 (22.05.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/576,424 22 May 2000 (22.05.2000) US

(63) Related by continuation (CON) or continuation-in-part (CIP) to earlier application:
US 09/576,424 (CON)
Filed on 22 May 2000 (22.05.2000)

(71) Applicant *(for all designated States except US)*: **IDEC PHARMACEUTICALS CORPORATION** [US/US]; 3030 Callan Road, San Diego, CA 92121 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **ANDERSON, Darrell, R.** [US/US]; 29246 Lawrence Welk Lane, Escondido, CA 92026 (US). **HANNA, Nabil** [US/US]; 14770 Avenida Insurgentes, Rancho Santa Fe, CA 92067 (US). **BRAMS, Peter** [DK/US]; 4303 Proctor Place, San Diego, CA 92116 (US).

(74) Agents: **TESKIN, Robin, L.** et al.; Pillsbury Winthrop LLP, 1600 Tysons Boulevard, McLean, VA 22102 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

**Published:**
— *with international search report*

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

WO 01/89567 A1

(54) Title: IDENTIFICATION OF UNIQUE BINDING INTERACTIONS BETWEEN CERTAIN ANTIBODIES AND THE HUMAN B7.1 AND B7.2 CO-STIMULATORY ANTIGENS

(57) Abstract: The present invention relates to the identification of antibodies which are specific to B7 antigens, e.g. human B7.1 antigen (CD80) and/or B7.2 antigen (CD86), which promote apoptosis of B7+ cells, preferably B cells. Also preferably, such antibodies are capable of inhibiting the binding of B7.1 to a CD28 receptor and which are not capable of inhibiting the binding of B7.1 to a CTLA-4 receptor. Two of the exemplified antibodies, 16C10 and 7C10, also significantly inhibit the production of IL-2. These antibodies are useful in treating conditions wherein apoptosis of B7+ cells is desirable, e.g. B cell tumors, lymphomas, leukemias or solid tumors or cancers wherein B cells promote tumor growth and/or metastasis, but wheren these B cells are not themselves cancerous.

# IDENTIFICATION OF UNIQUE BINDING INTERACTIONS BETWEEN CERTAIN ANTIBODIES AND THE HUMAN B7.1 AND B7.2 CO-STIMULATORY ANTIGENS

## FIELD OF THE INVENTION

The present invention relates to the identification and use of monoclonal antibodies which are specific to B7.1 (CD80) and/or B7.2 (CD86) antigen. More specifically, the present invention relates to the identification and use of monoclonal antibodies or primatized forms thereof which are capable of inhibiting the binding of human B7.1 (CD80) or B7.2 (CD86) antigen to a CD28 receptor and which are not capable of inhibiting the binding of B7.1 to a CTLA-4 receptor. Thus, the invention relates to the identification and use of monoclonal antibodies and primatized forms thereof which recognize specific sites on the B7.1 (CD80) or B7.2 (CD86) antigen which are not involved in CTLA-4 receptor binding.

The invention further relates to monoclonal antibodies or primatized forms thereof which recognize specific sites on the human B7.1 (CD80) and/or B7.2 (CD86) antigen and are capable of inhibiting IL-2 production.

Also, the present invention relates to pharmaceutical compositions containing monoclonal or primatized antibodies specific to human B7.1 (CD80) and B7.2 (CD86) and their use as immunosuppressants by modulating the B7:CD28 pathway, e.g., for the treatment of autoimmune disorders, and the prevention of organ rejection.

## BACKGROUND OF THE INVENTION

The clinical interface between immunology, hematology, and oncology has long been appreciated. Many conditions treated by the hematologist or oncologist have either an autoimmune or immuno-deficient component to their pathophysiology that has led to the widespread adoption of immunosuppressive medications by hematologists, whereas oncologists have sought immunologic adjuvants that might enhance endogenous immunity to tumors. To date, these interventions have generally consisted of nonspecific modes of immunosuppression and immune stimulation. In addition to the limited efficacy of these interventions, toxicities secondary to their nonspecificity have also limited their overall success. Therefore, alternative strategies have been sought.

Elucidation of the functional role of a rapidly increasing number of cell surface molecules has contributed greatly to the integration of immunology with clinical hematology and oncology. Nearly 200 cell surface antigens have been identified on cells of the immune and hematopoietic systems (Schlossman SF, Boumsell L, Gilks JM, Harlan T, Kishimoto, C Morimoto C, Ritz J., Shaw S, Silverstein RL, Springer TA, Tedder TF, Todd RF:CD antigens (1993), *Blood* 83:879, 1994). These antigens represent both lineage-restricted and more widely distributed molecules involved in a variety of processes, including cellular recognition, adhesion, induction and maintenance of proliferation, cytokine secretion, effector function, and even cell death. Recognition of the functional attributes of these molecules has fostered novel attempts to manipulate the immune response. Although molecules involved in cellular adhesion and antigen-specific recognition have previously been evaluated as targets of therapeutic immunologic intervention, recent attention has focused on a subgroup of cell surface molecules termed co-stimulatory molecules (Bretscher P: "The two-signal model of lymphocyte activation twenty-one years later." *Immunol. Today* 13:73 (1992); Jenkins MK, Johnson JG: "Molecules involved in T-cell co-stimulation." *Curr Opin Immunol* 5:351 (1993); Geppert T, Davis L. Gur H. Wacholtz M. Lipsky P: "Accessory cell signals involved in T-cell activation." *Immunol Rev* 117:5 (1990); Weaver CT, Unanue ER: "The co-stimulatory function of antigen-presenting cells." *Immunol Today* 11:49 (1990); Stennam RM, Young JW: "Signals arising from antigen-presenting cells." *Curr Opin Immunol* 3:361 (1991)). Co-stimulatory molecules do not initiate but rather enable the generation and amplification of antigen-specific T-cell responses and effector function (Bretscher P: "The two-signal model of lymphocyte activation twenty-one years later." *Immunol. Today* 13:73 (1992); Jenkins MK, Johnson JG: "Molecules involved in T-cell co-stimulation." *Curr Opin Immunol* 5:351 (1993); Geppert T, Davis L. Gur H. Wacholtz M. Lipsky P: "Accessory cell signals involved in T-cell activation." *Immunol Rev* 117:5 (1990); Weaver CT, Unanue ER: "The co-stimulatory function of antigen-presenting cells." *Immunol Today* 11:49, (1990); Stennam RM, Young JW: "Signals arising from antigen-presenting cells." *Curr Opin Immunol* 3:361 (1991); June CH,

Bluestone JA, Linsley PS, Thompson CD: "Role of the CD28 receptor in T-cell activation." *Immunol Today* 15:321 (1994)).

Recently, one specific co-stimulatory pathway termed B7:CD28 has been studied by different research groups because of its significant role in B- and T-cell activation (June CH, Bluestone JA, Linsley PS, Thompson CD: "Role of the CD28 receptor in T-cell activation." *Immunol Today* 15:321 (1994); June CH, Ledbetter JA: "The role of the CD28 receptor during T-cell responses to antigen.". *Annu Rev Immunol* 11:191 (1993); Schwartz RH: "Co-stimulation of T lymphocytes: The role of CD28, CTLA-4, and B7/BB1 in interleukin-2 production and immunotherapy." *Cell* 71:1065-1068 (1992); Jenkins MK, Taylor PS, Norton SD, Urdahl KB: "CD28 delivers a co-stimulatory signal involved in antigen-specific IL-2 production by human T cells." *Journal of Immunology* 147:2461-2466 (1991)). Since this ligand:receptor pathway was discovered four years ago, a large body of evidence has accumulated suggesting that B7:CD28 interactions represent one of the critical junctures in determining immune reactivity versus anergy (June CH, Bluestone JA, Linsley PS, Thompson CD: "Role of the CD28 receptor in T-cell activation." *Immunol Today* 15:321 (1994); June CH, Ledbetter JA: "The role of the CD28 receptor during T-cell responses to antigen." *Annu Rev Immunol* 11:191 (1993); Schwartz RH: "Co-stimulation of T lymphocytes: The role of CD28, CTLA-4, and B7/BB1 in interleukin-2 production and immunotherapy." *Cell* 71:1065-1068 (1992); Cohen J: "Mounting a targeted strike on unwanted immune responses" (news; comment). *Science* 257:751 (1992); Cohen J: "New protein steals the show as 'co-stimulator' of T cells" (news; comment). *Science* 262:844 (1993)).

In particular, the role of the human B7 antigens, i.e., human B7.1 (CD80) and B7.2 (CD86), has been reported to play a co-stimulatory role in T-cell activation. See, e.g., Gimmi CD, Freeman, GJ, Gribben JG, Sugita K, Freedman AS, Morimoto C, Nadler LM: "B-cell surface antigen B7 provides a costimulatory signal that induces T cells to proliferate and secrete interleukin 2." *Proc. Natl. Acad. Sci. (USA)* 88:6575-6579 (1991).

### 1. B7.1 and B7.2 Co-stimulatory Role in T Cell Activation

The elaboration of a successful immune response depends on a series of specific interactions between a T cell and an antigen presenting cell. Although the essential first step in this process depends upon the binding of antigen to the T cell receptor, in the context of the MHC class II molecule (Lane, P.J.L., F.M. McConnell, G.L. Schieven, E.A. Clark, and J.A. Ledbetter, (1990), "The Role of Class II Molecules in Human B Cell Activation." *The Journal of Immunology* 144:3684-3692), this interaction alone is not sufficient to induce all the events necessary for a sustained response to a given antigen (Schwartz, R.H. (1990), "A Cell Culture Model for T Lymphocyte Clonal Anergy." *Science* 248:1349; Jenkins, M.K. (1992), "The Role of Cell Division in the Induction of Clonal Anergy." *Immunology Today* 13:69; Azuma, M., M. Cayabyab, D. Buck, J.H. Phillips, and L.L. Lanier (1992), "Involvement of CD28 in MHC-unrestricted Cytotoxicity Mediated by a Human Natural Killer Leukemia Cell Line." *The Journal of Immunology* 149:1115-1123; Azuma, M., M. Cayabyab, D. Buck, J.H. Phillips, and L.L. Lanier (1992), "CD28 Interaction with B7 Costimulates Primary Allogeneic Proliferative Responses and Cytotoxicity Mediated by Small Resting T Lymphocytes." *J. Exp. Med.* 175:353-360); S.D. Norton, L. Zuckerman, K.B. Urdahl, R. Shefner, J. Miller, and M.K. Jenkins (1992), "The CD28 Ligand, B7, Enhances IL-2 Production by Providing a Costimulatory Signal to T Cells." *The Journal of Immunology* 149:1556-1561; R. H. Schwartz (1992), "Costimulation of T Lymphocytes: The Role of CD28, CTLA-4, and B7/BB1 in Interleukin-2 Production and Immunotherapy." *Cell* 71:1065-1068).

The involvement of certain other co-stimulatory molecules is necessary (Norton, S.D., L. Zuckerman, K.B. Urdahl, R. Shefner, J. Miller, and M.K. Jenkins (1992), "The CD28 Ligand, B7, Enhances IL-2 Production by Providing A Costimulatory Signal to T Cells." *The Journal of Immunology* 149:1556-1561)). "The homodimers CD28 and CTLA-4 expressed on T cells" (June, C.H., J.A. Ledbetter, P.S. Linsley, and C.B. Thompson (1990), "Role of the CD28 Receptor in T-Cell Activation." *Immunology Today* 11:211-216; Linsley, P.S., W. Brady, M. Urnes, L.S. Grosmaire, N.K. Damle, and J.A. Ledbetter (1991), "CTLA-4 is a Second Receptor for the B Cell Activation Antigen B7." *J. Exp. Med.* 174:561)), together with B7.1

(CD80) and B7.2 (CD86) expressed on antigen presenting cells, are major pairs of co-stimulatory molecules necessary for a sustained immune response (Azuma, M., H. Yssel, J.H. Phillips, H. Spits, and L.L. Lanier (1993), "Functional Expression of B7/BB1 on Activated T Lymphocytes." *J. Exp. Med.* 177:845-850; Freeman, G.J., A.S. Freedman, J.M. Segil, G. Lee, J.F. Whitman, and LM. Nadler (1989), "B7, A New Member of the Ig Superfamily with Unique Expression on Activated and Neoplastic B Cells." *The Journal of Immunology* 143:2714-2722; Hathcock, K.S., G. Laslo, H.B. Dickler, J. Bradshaw, P. Linsley, and R.J. Hodes (1993), "Identification of an Alternative CTLA-4 Ligand Costimulatory for T Cell Activation." *Science* 262:905-911; Hart, D.N.J., G.C. Starling, V.L. Calder, and N.S. Fernando (1993), "B7/BB-1 is a Leucocyte Differentiation Antigen on Human Dendritic Cells Induced by Activation." *Immunology* 79:616-620). It can be shown *in vitro* that the absence of these co-stimulatory signals leads to an aborted T cell activation pathway and the development of unresponsiveness to the specific antigen, or anergy. (*See*, e.g., Harding, F.A., J.G. McArthur, J.A. Gross, D.M. Raulet, and J.P. Allison (1992), "CD28 Mediated Signaling Co-stimulates Murine T Cells and Prevents Induction of Anergy in T Cell Clones." *Nature* 356:607-609; Gimmi, C.D., G.J. Freeman, J.G. Gribben, G. Gray, and L.M. Nadler (1993); "Human T-Cell Clonal Anergy is Induced by Antigen Presentation in the Absence of B7 Costimulation.", *Proc. Natl. Acad. Sci.* 90:6586-6590; Tan, P., C. Anasefti, J.A. Hansen, J. Melrose, M. Brunvand, J. Bradshaw, J.A. Ledbetter, and P.S. Linsley (1993), "Induction of Alloantigen-specific Hyporesponsiveness in Human T Lymphocytes by Blocking Interaction of CD28 with Its Natural Ligand B7/BB1." *J. Exp. Med.* 177:165-173). Achievement of *in vivo* tolerance constitutes a mechanism for immunosuppression and a viable therapy for organ transplant rejection and for the treatment of autoimmune diseases. This has been achieved in experimental models following the administration of CTLA-4Ig (Lenschow, D.J., Y. Zeng, R.J. Thistlethwaite, A. Montag, W. Brady, M.G. Gibson, P.S. Linsley, and J.A. Bluestone (1992), "Long-Term Survival of Xenogeneic Pancreatic Islet Grafts Induced by CTLA-4Ig." *Science* 257:789-795).

The molecules B7.1 (CD80) and B7.2 (CD86) can bind to either CD28 or CTLA-4, although B7.1 (CD80) binds to CD28 with a Kd of 200 Nm and to CTLA-4

with a 20-fold higher affinity (Linsley, P.S., E.A. Clark, and J.A. Ledbetter (1990), "T-Cell Antigen CD28 Mediates Adhesion with B Cells by Interacting with Activation Antigen B7/BB-1." *Proc. Natl. Acad. Sci.* 87:5031-5035; Linsley et al (1993), "The Role of the CD28 receptor during T cell responses to antigen," *Annu. Rev. Immunol.* 11:191-192; Linesley et al (1993), "CD28 Engagement by B7/BB-1 Induces Transient Down-Regulation of CD28 Synthesis and Prolonged Unresponsiveness to CD28 Signaling," *The Journal of Immunology* 150:3151-3169). B7.1 is expressed on activated B cells and interferon induced monocytes, but not resting B cells (Freeman, G.J., G.S. Gray, C.D. Gimmi, D.B. Lomarrd, L-J. Zhou, M. White, J.D. Fingeroth, J.G. Gribben, and LM. Nadler (1991). "Structure, Expression and T Cell Costimulatory Activity of the Murine Homologue of the Human B Lymphocyte Activation Antigen B7," *J. Exp. Med.*, 174:625-631). B7.2 (CD86), on the other hand, is constitutively expressed at very low levels on resting monocytes, dendritic cells and B cells, and its expression is enhanced on activated T cells, NK cells and B lymphocytes (Azuma, M. D. Ito, H. Yagita, K. Okumura, J.H. Phillips, L.L. Lanier, and C. Somoza 1993, "B70 Antigen is a Second Ligand for CTLA-4 and CD28," *Nature*, 366:76-79). Although B7.1 and B7.2 can be expressed on the same cell type, their expression on B cells occurs with different kinetics (Lenschow, D.J., G.H. Su, L.A. Zuckerman, N. Nabavi, C.L. Jellis, G.S. Gray, J. Miller, and J.A. Bluestone (1993), "Expression and Functional Significance of an Additional Ligand for CTLA-4," *Proc. Natl. Acad. Sci., USA*, 90:11054-11058; Boussiotis, V.A., G.J. Freeman, J.G. Gribben, J. Daley, G. Gray, and L.M. Nadler (1993), "Activated Human B Lymphocytes Express Three CTLA-4 Counter-receptors that Co-stimulate T-Cell Activation." *Proc. Natl. Acad. Sci., USA*, 90:11059-11063). Further analysis at the RNA level has demonstrated that B7.2 mRNA is constitutively expressed, whereas B7.1 mRNA is detected four hours after activation and initial low levels of B7.1 protein are not detectable until 24 hours after stimulation (Boussiotis, V.A., G.J. Freeman, J.G. Gribben, J. Daley, G. Gray, and L.M. Nadler (1993), "Activated Human B Lymphocytes Express Three CTLA-4 Counter-receptors that Co-stimulate T-Cell Activation," *Proc. Natl. Acad. Sci., USA*, 90:11059-11063). CTLA-4/CD28 counter receptors, therefore, may be expressed at various times after B Cell activation.

More recently, it has been suggested that the second T cell associated co-receptor CTLA-4 apparently functions as a negative modulator to override and prevent a runaway immune system (Krummel M, Allison J: "CD28 and CTLA-4 have opposing effects on the response of T cells to stimulation." *J. Exp. Med.* 182:459-466 (1995)). The CTLA-4 receptor plays a critical role in down regulating the immune response, as evidenced in CTLA-4 knockout mice. Knockout mice born without the ability to express the CTLA-4 gene die within 3-4 weeks of severe lymphoproliferative disorder (Tivol EA, Borriello G, Schweitzer AN, Lynch WP, Bluestone JA, Sharpe AH: "Loss of CTLA-4 leads to massive lymphoproliferation and fatal multiorgan tissue destruction, revealing a critical negative regulatory role of CTLA-4." *Immunity* 3:541-547 (1995)). CTLA-4 is thought to function through signaling mechanisms linked to induction of apoptosis (Gribben JG, Freeman GJ, Boussiotis VA, Rennert P, Jellis CL, Greenfield E, Barber M, Restivo Jr. VA, Ke X, Gray GS, Nadler LM: "CTLA-4 mediates antigen specific apoptosis of human T cells." *Proc. Natl. Acad. Sci. USA* 92:811-815 (1995)), triggered through as yet undefined ligand binding to specific cites on the receptor. It has been shown *in vitro* that the blocking of the B7.1/B7.2 dependent co-stimulatory signals in various ways leads to an aborted T cell activating pathway and the development of unresponsiveness to the specific antigen (Lederman S, Chess L, Yellin MJ: "Murine monoclonal antibody (5c8) recognizes a human glycoprotein on the surface of T-lymphocytes, compositions containing same." U.S. Patent No. 5,474,771 (December 12, 1995); Linsley PS, Ledbetter JA, Damle NK, Brady W: "Chimeric CTLA4 receptor and methods for its use." U.S. Patent No. 5,434,131 (July 18, 1995); Harding, 1992; Gimmi CD, Freeman GJ, Bribben JG, Gray G, Nadler LM: "Human T-cell clonal anergy is induced by antigen presentation in the absence of B7 costimulation." *Proc. Natl. Acad. Sci. (USA)* 90:6586-6590 (1993); Tan P, Anasetti C, Hansen JA, Melrose J, Brunvand M, Bradshaw J, Ledbetter JA, Linsley PS: "Induction of alloantigen-specific hyporesponsiveness in human T lymphocytes by blocking interaction of CD28 with its natural ligand B7/BB1." *J. Exp. Med.* 177:165-173 (1993)). Achievement of *in vivo* tolerance, anergy, or depleting of antigen-specific T

cells would constitute a mechanism for immunosuppression and a viable therapy for organ transplant rejection or plausible treatment for autoimmune diseases.

The differential temporal expression of B7.1 (CD80) and B7.2 (CD86) suggests that the interaction of these two molecules with CTLA-4 and/or CD28 deliver distinct but related signals to the T cell (LaSalle, J.M., P.J. Tolentino, G.J. Freeman, L.M. Nadler, and D.A. Hafler, (1992), "CD28 and T Cell Antigen Receptor Signal Transduction Coordinately Regulate Interleukin 2 Gene Expression In Response to Superantigen Stimulation," J. Exp. Med., 176:177-186; Vandenberghe, P., G.J. Freeman, L.M. Nadler, M.C. Fletcher, M. Kamoun, L.A. Turka, J.A. Ledbetter, C.B. Thompson, and C.H. June (1992), "Antibody and B7/BB1-mediated Ligation of the CD28 Receptor Induces Tyrosine Phosphorylation in Human T Cells," *The Journal of Experimental Medicine* 175:951-960)). The exact signaling functions of CTLA-4 and CD28 on the T cell are currently unknown (Janeway, C.A., Jr. and K. Bottomly, (1994), "Signals and Signs for Lymphocyte Responses," *Cell* 76.275285). However, it is possible that one set of receptors could provide the initial stimulus for T cell activation and the second, a sustained signal to allow further elaboration of the pathway and clonal expansion to take place (Linsley, P.S., J.L. Greene, P. Tan, J. Bradshaw, J.A. Ledbetter, C. Anasetti, and N.K. Damle, (1992), "Coexpression and Functional Cooperation of CTLA-4 and CD28 on Activated T Lymphocytes," *J. Exp. Med.* 176:1595-1604). The current data supports the two-signal hypothesis proposed by Jenkins and Schwartz (Schwartz, R.H. (1990), "A Cell Culture Model for T Lymphocyte Clonal Anergy," *Science* 248:1349; Jenkins, M.K., (1992), "The Role of Cell Division in the Induction of Clonal Anergy," *Immunology Today* 13:69)) that both a TCR and co-stimulatory signal are necessary for T cell expansion, lymphokine secretion and the full development of effector function (Greenan, V. and G. Kroemer (1993), "Multiple Ways to Cellular Immune Tolerance," *Immunology Today* 14:573). The failure to deliver the second signal results in the inability of T cells to secrete IL-2 and renders the cell unresponsive to antigen.

Structurally, both B7.1 (CD80) and B7.2 (CD86) contain extracellular immunoglobulin superfamily V and C-like domains, a hydrophobic transmembrane region and a cytoplasmic tail (Freeman, G.J., J.G. Gribben, V.A. Boussiotis, J.W. Ng,

V. Restivo, Jr., L.A. Lombard, G.S. Gray, and L.M. Nadler (1993), "Cloning of B7.2: A CTLA-4 Counter-receptor that Co-stimulates Human T Cell Proliferation," *Science* 262:909). Both B7.1 and B7.2 are heavily glycosylated. B7.1 is a 44-54kD glycoprotein comprised of a 223 amino acid extracellular domain, a 23 amino acid transmembrane domain, and a 61 amino acid cytoplasmic tail. B7.1 (CD80) contains 3 potential protein kinase phosphorylation sites. (Azuma, M., H. Yssel, J.H. Phillips, H. Spits, and L.L. Lanier, (1993), "Functional Expression of B7/BB1 on Activated T Lymphocytes," *J. Exp. Med.* 177:845-850). B7.2 (CD86) is a 306 amino acid membrane glycoprotein. It consists of a 220 amino acid extracellular region, a 23 amino acid hydrophobic transmembrane domain and a 60 amino acid cytoplasmic tail (Freeman, G.J., A.S. Freedman, J.M. Segil, G. Lee, J.F. Whitman, and LM. Nadler (1989), "B7, A New Member of the Ig Superfamily with Unique Expression on Activated and Neoplastic B Cells," *The Journal of Immunology* 143:2714-2722). Although both B7.1 (CD80) and B7.2 (CD86) genes are localized in the same chromosomal region (Freeman, G.J., D.B. Lombard, C.D. Gimmi, S.A. Brod, L Lee, J.C. Laning, D.A. Hafler, M.E. Dorf, G.S. Gray, H. Reiser, C.H. June, C.B. Thompson, and L.M. Nadler (1992), "CTLA-4 and CD28 mRNA are Coexpressed in Most T Cells After Activation," *The Journal of Immunology* 149:3795-3801; Schwartz, R.H. (1992), "Costimulation of T Lymphocytes: The Role of CD28, CTLA-4, and B7/BB1" in Selvakumar, A., B.K. Mohanraj, R.L. Eddy, T.B. Shows, P.C. White, C. Perrin, and B. Dupont (1992), "Genomic Organization and Chromosomal Location of the Human Gene Encoding the B-Lymphocyte Activation Antigen B7," *Immunogenetics* 36:175-181), these antigens do not share a high level of homology. The overall homology between B7.1 and B7.2 is 26% and between murine B7.1 and human B7.1 is 27% (Azuma, M., H. Yssel, J.H. Phillips, H. Spits, and L.L. Lanier (1993), "Functional Expression of B7/BB1 on Activated T Lymphocytes," *J. Exp. Med.* 177:845-850; Freeman, G.J., A.S. Freedman, J.M. Segil, G. Lee, J.F. Whitman, and LM. Nadler (1989), "B7, A New Member of the Ig Superfamily with Unique Expression on Activated and Neoplastic B Cells," *The Journal of Immunology* 143:2714-2722). Although alignment of human B7.1 human B7.2 and murine B7.1 sequences shows few stretches of lengthy homology, it is known that all three

molecules bind to human CTLA-4 and CD28. Thus, there is most likely a common, or closely homologous region shared by the three molecules that may be either contiguous or conformational. This region may constitute the binding site of the B7.1 and B7.2 molecules to their counter-receptors. Antibodies raised against these epitopes could potentially inhibit the interaction of B7 with its counter-receptor on the T cell. Furthermore, antibodies that cross-reacted with this region on both B7.1 and B7.2 molecules would potentially have practical advantages over antibodies directed against B7.1 or B7.2 separately.

**2. Blockade of the B7/CD28 Interaction**

Blocking of the B7/CD28 (CD80 and/or CD86) interaction offers the possibility of inducing specific immunosuppression, with potential for generating long lasting antigen-specific therapeutic effects. Antibodies or agents that temporarily prevent this interaction may be useful, specific and safe clinical immunosuppressive agents, with potential for generating long term antigen-specific therapeutic effects.

Antibodies to either B7.1 (CD80) or B7.2 (CD86) have been shown to block T cell activation, as measured by the inhibition of IL-2 production *in vitro* (DeBoer, M., P. Parren, J. Dove, F. Ossendorp, G. van der Horst, and J. Reeder (1992), "Functional Characterization of a Novel Anti-B7 Monoclonal Antibody," *Eur. Journal of Immunology* 22:3071-3075; Azuma, M., H. Yssel, J.H. Phillips, H. Spits, and L.L. Lanier (1993), "Functional Expression of B7/BB1 on Activated T Lymphocytes," *J. Exp. Med.* 177:845-850)). However, different antibodies have been shown to vary in their immunosuppressive potency, which may reflect either their affinity or epitope specificity. A possible explanation for this may reside in the ability of some antibodies to block only the binding of B7 (CD80 and/or CD86) to CD28, while promoting apoptosis or some other form of negative signaling through the CTLA-4 receptor in activated T cells. Some antibodies to B7.1 (CD80) or B7.2 (CD86) may, in fact, hinder the activity of CTLA-4 by cross-reacting with the CTLA-4 binding domain. CTLA-4Ig fusion protein and anti-CD28 Fabs were shown to have similar effects on the down regulation of IL-2 production.

*In vivo* administration of a soluble CTLA-4Ig fusion protein has been shown to suppress T cell dependent antibody responses in mice (Linsley, P.S., J.L. Greene, P.

Tan, J. Bradshaw, J.A. Ledbetter, C. Anasetti, and N.K. Damle (1992), "Coexpression and Functional Cooperation of CTLA-4 and CD28 on Activated T Lymphocytes," *J. Exp. Med.* 176:1595-1604; Lin, H., S.F. Builing, P.S. Linsley, R.O. Wei, C.D. Thompson, and L.A. Turka (1993), "Long-term Acceptance of Major Histocompatibility Complex Mismatched Cardiac Allografts Induced by CTLA-4-Ig Plus Donor Specific Transfusion," *J. Exp. Med.* 178:1801) and, furthermore, larger doses were also able to suppress responses to a second immunization, demonstrating the feasibility of this approach for the treatment of antibody mediated autoimmune disease. In addition, CTLA-4Ig was able to prevent pancreatic islet cell rejection in mice by directly inhibiting the interaction of T cells and B7.1/B7.2 antigen presenting cells (Lenschow, D.J., G.H. Su, L.A. Zuckerman, N. Nabavi, C.L. Jellis, G.S. Gray, J. Miller, and J.A. Bluestone (1993), "Expression and Functional Significance of an Additional Ligand for CTLA-4," *Proc. Natl. Acad. Sci., USA* 90:11054-11058). In this case, long term donor specific tolerance was achieved.

**3. Recombinant Phage Display Technology for Antibody Selection**

To date, no monoclonal antibodies which cross-react with both B7.1 (CD80) and B7.2 (CD86) have been reported. Furthermore, no monoclonal antibodies which are specific to B7.1 (CD80) or B7.2 (CD86) and which also recognize specific sites on the antigens which are restricted to co-activation receptor CD28 binding have been reported. Or alternatively, no monoclonal antibodies which are specific to B7.1 (CD80) or B7.2 (CD86) and which recognize specific sites on the antigens which are exclusive of CTLA-4 receptor binding have been reported. As discussed supra, such antibodies would potentially be highly desirable as immunosuppressants.

Phage display technology is beginning to replace traditional methods for isolating antibodies generated during the immune response, because a much greater percentage of the immune repertoire can be assessed than is possible using traditional methods. This is in part due to PEG fusion inefficiency, chromosomal instability, and the large amount of tissue culture and screening associated with heterohybridoma production. Phage display technology, by contrast, relies on molecular techniques for potentially capturing the entire repertoire of immunoglobulin genes associated with the response to a given antigen.

This technique is described by Barbas et al, *Proc. Natl. Acad. Sci., USA* 88:7978-7982 (1991). Essentially, immunoglobulin heavy chain genes are PCR amplified and cloned into a vector containing the gene encoding the minor coat protein of the filamentous phage M13 in such a way that a heavy chain fusion protein is created. The heavy chain fusion protein is incorporated into the M13 phage particle together with the light chain genes as it assembles. Each recombinant phage contains, within its genome, the genes for a different antibody Fab molecule which it displays on its surface. Within these libraries, in excess of $10^6$ different antibodies can be cloned and displayed. The phage library is panned on antigen coated microliter wells, non-specific phage are washed off, and antigen binding phage are eluted. The genome from the antigen-specific clones is isolated and the gene III is excised, so that antibody can be expressed in soluble Fab form for further characterization. Once a single Fab is selected as a potential therapeutic candidate, it may easily be converted to a whole antibody. A previously described expression system for converting Fab sequences to whole antibodies is IDEC's mammalian expression vector NEOSPLA. This vector contains either human gamma 1 or gamma 4 constant region genes. CHO cells are transfected with the NEOSPLA vectors and after amplification this vector system has been reported to provide very high expression levels (> 30 pg/cell/day) can be achieved.

**4. Primatized Antibodies**

Another highly efficient means for generating recombinant antibodies is disclosed by Newman (1992), *Biotechnology* 10, 1455-1460. More particularly, this technique results in the generation of primatized antibodies which contain monkey variable domains and human constant sequences. This reference is incorporated by reference in its entirety herein. Moreover, this technique is also described in U.S. Patent No. 5,658,570. U.S. Patent No. 5,658,570 is incorporated by reference in its entirety herein.

This technique modifies antibodies such that they are not antigenically rejected upon administration in humans. This technique relies on immunization of cynomolgus monkeys with human antigens or receptors. This technique was

developed to create high affinity monoclonal antibodies directed to human cell surface antigens.

Identification of macaque antibodies to human B7.1 (CD80) and B7.2 (CD86) by screening of phage display libraries or monkey heterohybridomas obtained using B lymphocytes from B7.1 (CD80) and/or B7.2 (CD86) immunized monkeys is also described in commonly assigned U.S. Application No. 08/487,550, filed June 7, 1995, incorporated by reference in its entirety herein. More specifically, 08/487,550 provides four monoclonal antibodies 7B6, 16C10, 7C10 and 20C9 which inhibit the B7:CD28 pathway and thereby function as effective immunosuppressants.

Antibodies generated in the manner described by these co-assigned applications have previously been reported to display human effector function, have reduced immunogenicity, and to exhibit long serum half-life. The technology relies on the fact that despite the fact that cynomolgus monkeys are phylogenetically similar to humans, they still recognize many human proteins as foreign and therefore mount an immune response. Moreover, because the cynomolgus monkeys are phylogenetically close to humans, the antibodies generated in these monkeys have been discovered to have a high degree of amino acid homology to those produced in humans. Indeed, after sequencing macaque immunoglobulin light and heavy chain variable region genes, it was found that the sequence of each gene family was 85-98% homologous to its human counterpart (Newman et al, (1992), *Id.*). The first antibody generated in this way, an anti-CD4 antibody, was 91-92% homologous to the consensus sequence of human immunoglobulin framework regions. Newman et al, *Biotechnology* 10:1458-1460 (1992).

Monoclonal antibodies specific to the human B7 antigen have been previously described in the literature. For example, Weyl et al, *Hum. Immunol.* 31(4), 271-276 (1991) describe epitope mapping of human monoclonal antibodies against HLA-B-27 using natural and mutated antigenic variants. Also, Toubert et al, *Clin. Exp. Immunol.* 82(1), 16-20 (1990) describe epitope mapping of an HLA-B27 monoclonal antibody that also reacts with a 35-KD bacterial outer membrane protein. Also, Valle et al, *Immunol.* 69(4), 531-535 (1990) describe a monoclonal antibody of the IgG1 subclass which recognizes the B7 antigen expressed in activated B cells and HTLV-1-

transformed T cells. Further, Toubert et al, *J. Immunol.* 141(7), 2503-9 (1988) describe epitope mapping of HLA-B27 and HLA-B7 antigens using intradomain recombinants constructed by making hybrid genes between these two alleles in *E. coli*.

High expression of B7 antigens has been correlated to autoimmune diseases by some researchers. For example, Ionesco-Tirgoviste et al, *Med. Interre* 24(1), 11-17 (1986) report increased B7 antigen expression in type 1 insulin-dependent diabetes. Also, increased B7 antigen expression on dermal dendritic cells obtained from psoriasis patients has been reported. (Nestle et al, *J. Clin. Invest.* 94(1), 202-209 (1994)).

Further, the inhibition of anti-HLA-B7 alloreactive CTL using affinity-purified soluble HLA-B7 has been reported in the literature. (Zavazava et al, *Transplantation* 51(4), 838-42 (1991)). Further, the use of B7 receptor soluble ligand, CTLA-4-Ig to block B7 activity (*See*, e.g., Lenschow et al, *Science* 257, 789, 7955 (1992)) in animal models and a B7.1-Ig fusion protein capable of inhibiting B7 has been reported.

Evidence is provided in this disclosure for the identification of monoclonal antibodies which recognize specific sites on the B7.1 antigen which are restricted to CD28 receptor binding. Furthermore, evidence is presented herein for the identification of antibodies which recognize sites on the B7.1 and/or B7.2 antigen which are exclusive of CTLA-4 receptor binding. Thus, evidence is presented herein to support the existence of unique antigen binding sites on the human B7.1 (CD80) co-stimulatory antigen. The sites claimed are identified by anti-B7.1 PRIMATIZED® antibodies and evidence is presented which confirms binding to a site of interaction on the B7.1 antigen which is restricted to binding with the co-activation receptor CD28.

## SUMMARY AND OBJECTS OF THE INVENTION

An object of the invention is to identify novel antibodies which are specific to human B7.1 antigen. More specifically, it is an object of the invention to identify antibodies which are specific to human B7.1 antigen and which are also capable of inhibiting the binding of B7.1 to a CD28 receptor. It is also an object of this invention to identify antibodies which are specific to human B7.1 antigen and which are not

capable of inhibiting the binding of B7.1 to a CTLA-4 receptor. Thus, an object of this invention is to identify antibodies which recognize specific sites on the B7.1 antigen, wherein the recognized sites are restricted to CD28 receptor binding and which are exclusive of CTLA-4 receptor binding.

It is a further object of the invention to identify antibodies which are specific to human B7.1 (CD80) antigen and which fail to recognize human B7.2 (CD86) antigen.

It is another object of the invention to identify monoclonal antibodies and primatized forms thereof which recognize specific sites on the human B7.1 antigen and which inhibit IL-2 production and T cell proliferation and which function as effective immunosuppressants. More specifically, it is an object of this invention to identify antibodies which are specific to B7.1 (CD80) and which are capable of inhibiting IL-2 production. It is another object of the invention to provide monoclonal antibodies and primatized forms thereof which inhibit antigen driven responses in donor spleen cell cultures, e.g., antigen specific IgG responses, IL-2 production and cell proliferation.

It is another specific object of the invention to identify particular monoclonal antibodies specific to human B7.1 (CD80) antigen and primatized forms thereof having advantageous properties, i.e., affinity, immunosuppressive activity, which are useful as therapeutics. More specifically, these antibodies and primatized forms thereof are to be used, e.g., as immunosuppressants, i.e., to block antigen driven immune responses, to treat autoimmune diseases such as psoriasis, rheumatoid arthritis, systemic erythematosus (SLE), type 1 diabetes mellitus, idiopathic thrombocytopenia purpura (ITP), allergy, inflammatory bile disease, and to prevent organ rejection.

It is another object of the invention to provide pharmaceutical compositions containing one or more monoclonal antibodies specific to human B7.1 (CD80) antigen or primatized forms thereof, and a pharmaceutically acceptable carrier or excipient. These compositions will be used, e.g., as immunosuppressants to treat autoimmune diseases, e.g., idiopathic thrombocytopenia purpura (ITP) and systemic

lupus erythematosus (SLE), to block antigen driven immune responses, and to prevent organ rejection in transplant recipients.

It is another object of the invention to provide novel methods of therapy by administration of therapeutically effective amounts of one or more or primatized monoclonal antibodies which specifically bind to human B7.1 antigen. Such therapeutic methods are useful for treatment of diseases treatable by inhibition of the B7:CD28 pathway, e.g., autoimmune diseases such as idiopathic thrombocytopenia purpura (ITP), systemic lupus erythematosus (SLE), type 1 diabetes mellitus, psoriasis, rheumatoid arthritis, multiple sclerosis, aplastic anemia, as well as for preventing rejection in transplantation subjects.

It is another object of the invention to provide antibodies specific to B7.1 and/or B7.2 antigen that induce apoptosis of B7 expressing cells, e.g. B cells and preferably lymphoma cells.

It is still another object of the invention to provide transfectants, e.g., CHO cells, which express at least the variable heavy and light domains of monoclonal antibodies specific to the human B7.1 antigen and/or B7.2 antigen.

**Definitions**

The following terms are defined so that the invention may be more clearly understood.

Depleting antibody - an antibody which kills activated B cells or other antigen presenting cells.

Non-depleting antibody - an antibody which blocks the co-stimulatory action of B7 and T cell activating ligands CD28 and CTLA-4. Thus, it anergizes but does not eliminate the antigen presenting cell.

Primatized antibody - a recombinant antibody which has been engineered to contain the variable heavy and light domains of a monkey antibody, in particular, a cynomolgus monkey antibody, and which contains human constant domain sequences, preferably the human immunoglobulin gamma 1 or gamma 4 constant domain (or PE variant). The preparation of such antibodies is described in Newman et al, (1992), "Primatization of Recombinant Antibodies for Immunotherapy of Human Diseases: A Macaque/Human Chimeric Antibody Against Human CDH, *Biotechnology* 10:1458-

1460; also in commonly assigned U.S. Serial No. 08/379,072, now U.S. Patent No. 5,658,570, both of which are incorporated by reference in their entirety herein. These antibodies have been reported to exhibit a high degree of homology to human antibodies, i.e., 85-98%, display human effector functions, have reduced immunogenicity, and may exhibit high affinity to human antigens.

B7 antigens - B7 antigens in this application include, e.g., human B7, B7.1 and B7.2 antigens. These antigens bind to CD28 and/or CTLA-4. These antigens have a co-stimulatory role in T cell activation. Also, these B7 antigens all contain extracellular immunoglobulin superfamily V and C-like domains, a hydrophobic transmembrane region and a cytoplasmic tail (*See*, Freeman et al, *Science* 262:909, (1993)), and are heavily glycosylated.

Anti-B7 antibodies - Antibodies, preferably monkey monoclonal antibodies or primatized forms thereof, which specifically bind human B7 antigens, e.g., human B7.1 and/or B7.2 antigen with a sufficient affinity to block the B7:CD28 interaction, but h do not block the B7/CTLA-4 receptor interaction and thereby induce immunosuppression.

Apoptosis-inducing Antibody – An antibody that induces programmed cell death ("apoptosis"). There are known assays for detecting apoptosis including capsage activation assays.

## BRIEF DESCRIPTION OF THE FIGURES

Figure 1 depicts the pMS vector used to screen recombinant immunoglobulin libraries produced against B7 displayed on the surface of filamentous phage which contains primers based on macaque immunoglobulin sequences.

Figure 2 depicts the NEOSPLA expression vector used to express the subject primatized antibodies specific to human B7.1 antigen.

Figure 3a depicts the amino acid and nucleic acid sequence of a primatized form of the light chain of 7C10.

Figure 3b depicts the amino acid and nucleic acid sequence of a primatized form of the heavy chain of 7C10.

Figure 4a depicts the amino acid and nucleic acid sequence of a primatized form of the light chain of 7B6.

Figure 4b depicts the amino acid and nucleic acid sequence of a primatized form of the heavy chain of 7B6.

Figure 5a depicts the amino acid and nucleic acid sequence of a primatized light chain 16C10.

Figure 5b depicts the amino acid and nucleic acid sequence of a primatized heavy chain 16C10.

Figure 6 depicts the inability of P16C10 to block CTLA-4Ig-Biotin binding to B7.1 transfected CHO cells.

Figure 7 depicts the inability of CTLA-4Ig to block P16C10-Biotin binding to B7.1 transfected CHO cells.

Figure 8 depicts that BB-1 completely blocks binding of CTLA-4Ig-Biotin to B7.1 transfected CHO cells and further depicts the inability of BB-1 to significantly affect P16C10-Biotin binding to B7.1 transfected CHO cells.

Figure 9 depicts that CTLA-4Ig-Biotin is effectively blocked by all B7.1 inhibitors except P16C10.

Figure 10 depicts the ability of P16C10 to block binding of the CD28/B7-1Ig interaction. Data shown are averages of values obtained from four separate experiments.

Figure 11 depicts production of IL-2 in cultures of purified normal human CD4+ lymphocytes when stimulated with sub-optimal amounts of immobilized anti-CD3 antibody and B7-1 (CD80) on latex microbeads. L307.4 is a commercially available murine antibody (B/D Pharmingen) that binds specifically to human CD80 and neutralizes CD28:CD80 functional interactions. CTLA-4Ig is a soluble receptor fusion protein that specifically blocks CD80 and CD86 binding to CD28 receptors on T cells. IDEC-114 is a PRIMATIZED monoclonal antibody that specifically binds to both soluble and membrane forms of the CD80 antigen but does not recognize CTLA-4 or B7-2 antigens. The ratio of anti-CD3 to B7Ig used in the cultures to stimulate T cells was 1:10 (w/w).

Figure 12 depicts uptake of H3-Thymidine in cultures of purified normal human CD4+ lymphocytes when stimulated with sub-optimal amounts of immobilized anti-CD3 antibody and B7-1 (CD80) on latex microbeads. L307.4 is a commercially available murine antibody (B/D Pharmingen) that binds specifically to human CD80 and neutralizes CD28:CD80 functional interactions. CTLA-4Ig is a soluble receptor fusion protein that specifically blocks CD80 and CD86 binding to CD28 receptors on T cells. IDEC-114 is a PRIMATIZED monoclonal antibody that specifically binds to both soluble and membrane forms of the CD80 antigen but does not recognize CTLA-4 or B7-2 antigens.

Figure 13 depicts production of TH2 cytokine IL-10 in cultures of purified normal human CD4+ lymphocytes when stimulated with sub-optimal amounts of immobilized anti-CD3 antibody and B7-1 (CD80) on latex microbeads. Inhibition of IL-10 production by L307.4 anti-CD80 and CTLA-4Ig fusion protein was compared at 0.1,1, and 10μg/mL.

Figure 14 depicts inhibition of IL-2 cytokine production by CTLA-4Ig and IDEC-114 in cultures of purified human CD4+ T cells. T cells were co-stimulated with anti-CD3 and B7Ig coated latex microbeads with an anti-CD3/B7 ratio (w/w) of 8:1. IL-2 was determined by growth and uptake of Thymidine by the IL-2 dependent cell line CTLL-2.

## DETAILED DESCRIPTION OF THE INVENTION

As described above, the present invention relates to the identification of monoclonal antibodies or primatized forms thereof which are specific to human B7.1 and/or B7.2 antigen and which are capable of inhibiting the binding of B7.1 to a CD28 receptor and which are not capable of inhibiting the binding of B7.1 to a CTLA-4 receptor. Preferably, these antibodies will induce apoptosis and/or potentiate apoptosis in combination with other agents, e.g. chemotherapy. Blocking of the primary activation site between CD28 and B7.1 (CD80) with the identified antibodies while allowing the combined antagonistic effect on positive co-stimulation with an agnostic effect on negative signaling will be a useful therapeutic approach for intervening in relapsed forms of autoimmune disease. The functional activity of the

identified antibodies is defined by blocking the production of the T cell stimulatory cytokine IL-2. Identified antibodies have demonstrated the ability to block the production of IL-2 in excess of 50%, in spite of the existence of a second actuating ligand B7.2, suggesting an alternate mechanism of action exists which is not typical of the observed effects of other anti-B7.1 antibodies defined in the literature.

Manufacture of novel monkey monoclonal antibodies which specifically bind human B7.1 and/or human B7.2 antigen, as well as primatized antibodies derived therefrom is described herein. These antibodies possess high affinity to human B7.1 and/or B7.2 and may be used as immunosuppressants and/or to induce apoptosis of B7 antigen expressing cells, e.g. B cells.

Preparation of monkey monoclonal antibodies will preferably be effected by screening of phage display libraries or by preparation of monkey heterohybridomas using B lymphocytes obtained from B7 [e.g., human B7.1 (CD80) and/or B7.2 (CD86)] immunized monkeys.

As noted, the first method for generating anti-B7 antibodies involves recombinant phage display technology. This technique is generally described *supra*.

Essentially, this will comprise synthesis of recombinant immunoglobulin libraries against B7 antigen displayed on the surface of filamentous phage and selection of phage which secrete antibodies having high affinity to B7.1 and/or B7.2 antigen. As noted *supra*, preferably antibodies will be selected which bind to both human B7.1 and B7.2. To effect such methodology, the present inventors have created a unique library for monkey libraries which reduces the possibility of recombination and improves stability. This vector, PMS, is described in detail *infra*, and is shown in Figure 1.

Essentially, to adopt phage display for use with macaque libraries, this vector contains specific primers for PCR amplifying monkey immunoglobulin genes. These primers are based on macaque sequences obtained while developing the primatized technology and databases containing human sequences.

Suitable primers are disclosed in commonly assigned U.S. Patent No. 5,658,570.

The second method involves the immunization of monkeys, i.e., macaques, against human B7 antigen, preferably against human B7.1 and B7.2 antigen. The inherent advantage of macaques for generation of monoclonal antibodies is discussed *supra*. In particular, such monkeys, i.e., cynomolgus monkeys, may be immunized against human antigens or receptors. Moreover, the resultant antibodies may be used to make primatized antibodies according to the methodology of Newman et al, *Biotechnology* 10, 1455-1460 (1992), and Newman et al, commonly assigned U.S. Serial No. U.S. Patent No. 5,658,570, which are incorporated by reference in their entirety.

The significant advantage of antibodies obtained from cynomolgus monkeys is that these monkeys recognize many human proteins as foreign and thereby provide for the formation of antibodies, some with high affinity to desired human antigens, e.g., human surface proteins and cell receptors. Moreover, because they are phylogenetically close to humans, the resultant antibodies exhibit a high degree of amino acid homology to those produced in humans. As noted above, after sequencing macaque immunoglobulin light and heavy variable region genes, it was found that the sequence of each gene family was 85-88% homologous to its human counterpart (Newman et al, (1992), *Id.*).

Essentially, cynomolgus macaque monkeys are administered human B7 antigen, e.g., human B7.1 (CD80) and/or human B7.2 (CD86) antigen, B cells are isolated therefrom, e.g., lymph node biopsies are taken from the animals, and B lymphocytes are then fused with KH6/B5 (mouse x human) heteromyeloma cells using polyethylene glycol (PEG). Heterohybridomas secreting antibodies which bind human B7 antigen, e.g., human B7.1 (CD80) and/or human B7.2 (CD86) antigen, are then identified.

Antibodies which bind to both B7.1 and B7.2 are desirable because such antibodies potentially may be used to inhibit the interaction of B7.1 (CD80) and B7.2 (CD86), as well as B7 with their counter-receptors, i.e., human CTLA-4 and CD28. Antibodies against these epitopes may inhibit the interaction of both human B7.1 (CD80) and human B7.2 (CD86) with their counter receptors on the T cell. This may potentially provide synergistic effects.

However, antibodies which bind to only one of human B7 antigen, B7.1 antigen or B7.2 antigen, are also highly desirable because of the co-involvement of these molecules in T cell activation, clonal expansion lymphokine (IL-2) secretion, and responsiveness to antigen. Given that both human B7.1 (CD80) and B7.2 (CD86) bind to human CTLA-4 and CD28, it is probable that there is at least one common or homologous region (perhaps a shared conformational epitope or epitopes) to which macaque antibodies may potentially be raised.

The disclosed invention involves the use of an animal which is primed to produce a particular antibody. Animals which are useful for such a process include, but are not limited to, the following: mice, rats, guinea pigs, hamsters, monkeys, pigs, goats and rabbits.

A preferred means of generating human antibodies using SCID mice is disclosed in U.S. Patent 5,811,524.

The present inventors elected to immunize macaques against human B7.1 antigen using recombinant soluble B7.1 antigen produced in CHO cells and purified by affinity chromatography using a L307.4-sepharose affinity column. However, the particular source of human B7 antigen, human B7.1 (CD80) antigen or human B7.2 (CD86) antigen is not critical, provided that it is of sufficient purity to result in a specific antibody response to the particular administered B7 antigen and potentially to other B7 antigens.

The human B7 antigen, human B7.1 antigen (CD80) and human B7.2 antigen (CD86) genes have been cloned, and sequenced, and therefore may readily be manufactured by recombinant methods.

Preferably, the administered human B7 antigen, human B7.1 (CD80) antigen and/or human B7.2 (CD86) antigen will be administered in soluble form, e.g., by expression of a B7, B7.1 (CD80) or B7.2 (CD86) gene which has its transmembrane and cytoplasmic domains removed, thereby leaving only the extracellular portion, i.e., the extracellular superfamily V and C-like domains. (*See*, e.g., Grumet et al, *Hum. Immunol.* 40(3), p. 228-234 (1994), which teaches expression of a soluble form of human B7, which is incorporated by reference in its entirety herein)).

The macaques will be immunized with the B7antigen, e.g., B7.1 (CD80) and/or B7.2 (CD86) antigen, preferably a soluble form thereof, under conditions which result in the production of antibodies specific thereto. Preferably, the soluble human B7 antigen, e.g., B7.1 (CD80) or B7.2 (CD86) antigen will be administered in combination with an adjuvant, e.g., Complete Freund's Adjuvant (CFA), Alum, Saponin, or other known adjuvants, as well as combinations thereof. In general, this will require repeated immunization, e.g., by repeated injection, over several months. For example, administration of soluble B7.1 (CD80) antigen was effected in adjuvant, with booster immunizations, over a 3 to 4 month period, with resultant production of serum containing antibodies which bound human B7.1 (CD80) antigen.

After immunization B cells are collected, e.g., by lymph node biopsies taken from the immunized animals and B lymphocytes fused with KH6/B5 (mouse x human) heteromyeloma cells using polyethylene glycol. Methods for preparation of such heteromyelomas are known and may be found in U.S. Patent No. 5,658,570, by Newman et al.

Heterohybridomas which secrete antibodies which bind human B7 antigen, e.g. B7.1 (CD80) and/or B7.2 (CD86) are then identified. This may be effected by known techniques. For example, this may be determined by ELISA or radioimmunoassay using enzyme or radionucleotide labelled human B7 antigen, e.g. B7.1 (CD80) and/or B7.2 (CD86) antigen.

Cell lines which secrete antibodies having the desired specificity to human B7 antigen, e.g. B7.1 (CD80) and/or B7.2 (CD86) antigen are then subcloned to monoclonality.

In the present invention, the inventors screened purified antibodies for their ability to bind to soluble B7.1 (CD80) antigen coated plates in an ELISA assay, antigen positive B cells, and CHO transfectomas which express human B7.1 (CD80) antigen on their cell surface. In addition, the antibodies were screened for their ability to block B cell/T cell interactions as measured by IL-2 production and tritiated thymidine uptake in a mixed lymphocyte reaction (MLR), with B7 binding being detected using $^{125}$I-radiolabeled soluble B7.1 (soluble B7.1 antigen).

Also, affinity purified antibodies from macaques were tested for their reactivity against CHO transfectants which expressed B7.1/Ig fusion proteins, and against CHO cells which produced human B7.2 (CD86) antigen. These results indicated that the B7.1 (CD80) immune sera bound to the B7.2 (CD86) transfectomas. Binding of antibodies to B7.2 (CD86) antigen may be confirmed using soluble B7.2-Ig reagents. As discussed in the examples, this may be effected by producing and purifying B7.2-Ig from CHO transfectomas in sufficient quantities to prepare a B7.2-Ig-sepharose affinity column. Those antibodies which cross-react with B7.2 (CD86) will bind the B7.2-Ig-sepharose column.

Cell lines which express antibodies which specifically bind to human B7 antigen, B7.1 (CD80) antigen and/or B7.2 (CD86) antigen are then used to clone variable domain sequences for the manufacture of primatized antibodies essentially as described in Newman et al (1992), *Id.* and Newman et al, U.S. Serial No. 379,072, filed January 25, 1995, both of which are incorporated by reference herein. Essentially, this entails extraction of RNA therefrom, conversion to cDNA, and amplification thereof by PCR using Ig specific primers. Suitable primers are described in Newman et al, 1992, *Id.* and in U.S. Serial No. 379,072. (*See*, in particular, Figure 1 of U.S. Serial No. 379,072).

The cloned monkey variable genes are then inserted into an expression vector which contains human heavy and light chain constant region genes. Preferably, this is effected using a proprietary expression vector of IDEC, Inc., referred to as NEOSPLA. This vector is shown in Figure 2 and contains the cytomegalovirus promoter/enhancer, the mouse beta globin major promoter, the SV40 origin of replication, the bovine growth hormone polyadenylation sequence, neomycin phosphotransferase exon 1 and exon 2, human immunoglobulin kappa or lambda constant region, the dihydrofolate reductase gene, the human immunoglobulin gamma 1 or gamma 4 PE constant region and leader sequence. This vector has been found to result in very high level expression of primatized antibodies upon incorporation of monkey variable region genes, transfection in CHO cells, followed by selection in G418 containing medium and methotrexate amplification.

For example, this expression system has been previously disclosed to result in primatized antibodies having high avidity (Kd $\leq 10^{-10}$ M) against CD4 and other human cell surface receptors. Moreover, the antibodies have been found to exhibit the same affinity, specificity and functional activity as the original monkey antibody. This vector system is substantially disclosed in commonly assigned U.S. Patent No. 5,658,570, incorporated by reference herein, as well as U.S. Serial No. 08/149,099, now U.S. Patent No. 5,736,137, also incorporated by reference in its entirety herein. This system provides for high expression levels, i.e., > 30 pg/cell/day.

As discussed *infra*, the subject inventors have selected four lead candidate monkey monoclonal antibodies which specifically bind the B7.1 antigen. These monkey monoclonal antibodies are referred to herein as 7B6, 16C10, 7C10 and 20C9.

As discussed in greater detail *infra*, these antibodies were evaluated for their ability to block B cell/T cell interactions as measured by IL-2 production and tritiated thymidine uptake in a mixed lymphocyte reaction for T cell binding experiments for T cell binding, human buffy coat peripheral blood lymphocytes were cultured for 3-6 days in the presence of PHA stimulator. B7 binding was radioassayed using $^{125}$I-radiolabeled soluble B7.1. The observed results indicate that all of these antibodies bind B7.1 antigen with high affinity and effectively block B cell/T cell interactions as evidenced by reduced IL-2 production and reduced proliferation of mixed lymphocyte cultures.

The properties of these particular monkey monoclonal antibodies are summarized below:

1. Scatchard analysis showed that the apparent affinity constants (Kd) for the monkey antibodies binding to B7-Ig coated plates were approximated to be:
   - a: 7C10: $6.2 \times 10^{-9}$M
   - b: 16C10: $8.1 \times 10^{-9}$M
   - c: 7B6: $10.7 \times 10^{-9}$M
   - d: 20C9: $16.8 \times 10^{-9}$M
2. The antibodies were tested *in vitro* in a mixed lymphocyte reaction assay (MLR). The MLR showed that all 4 anti-B7.1 antibodies inhibit

IL-2 production to different extents as shown by the following $Ic_{50}$ values:

a: 7B6: 5.0 μg/M

b: 16C10:<0.1 μg/M

c: 20C9: 2.0 μg/M

d: 7C10: 5.0 μg/M

3. The monkey anti-B7.1 antibodies were tested for their ability to bind B7 on human peripheral blood lymphocytes (PBL). FACS analysis showed that all 4 monkey antibodies tested positive.

4. Monkey antibodies 16C10, 7B6, 7C10 and 20C9 were tested for C1q binding by FACS analysis. Results showed 7C10 monkey Ig had strong human C1q binding after incubating with B7.1 CHO-transfected cells. 16C10 was positive, while 20C9 and 7B6 monkey antibodies were negative.

5. To select an animal model for path-tox studies, the monkey antibodies were tested with animal blood from different species. It was determined that the monkey anti-B7.1 antibodies cross-reacted with human, chimpanzee.

Based on these properties, it would appear that three monkey monoclonal antibodies possess the most advantageous properties, 16C10, 7C10 and 20C9, with 16C10 and 7C10 being somewhat better than 20C9.

Using the techniques described *supra*, and in commonly assigned U.S. Patent No. 5,658,570, the present inventors have cloned the variable domains of 7C10, 7B6 and 16C10, and provide the amino acid and nucleic acid sequences of primatized forms of the 7C10 light chain, 7C10 heavy chain, 7B6 light chain, 7B6 heavy chain, 16C10 light chain and 16C10 heavy chain. These amino acid and nucleic acid sequences may be found in Figures 3a and 3b, 4a and 4b, and 5a and 5b. The DNA and amino acid sequence for the human gamma 1, gamma 4 constant domain may be found in U.S. Patent No. 5,658,570.

As discussed *supra*, these primatized antibodies are preferably expressed using the NEOSPLA expression vector shown in Figure 2 which is substantially described

in commonly assigned U.S. Patent No. 5,658,570, and U.S. Patent No. 5,736,137, incorporated by reference herein in its entirety.

As previously noted, the subject primatized antibodies will preferably contain either the human immunoglobulin gamma 1 or gamma 4 constant region, with gamma 4 preferably mutated at two positions to create gamma 4 PE. The gamma 4 PE mutant contains two mutations, a glutamic acid in the CH2 region introduced to eliminate residual FCR binding, and a proline substitution in the hinge region, intended to enhance the stability of the heavy chain disulfide bond interaction. (*See*, Alegre et al, *J. Immunol.* 148, 3461-3468 (1992); and Angel et al, *Mol. Immunol.* 30, 105-158 (1993), both of which are incorporated by reference herein).

Whether the subject primatized antibodies contain the gamma 1, gamma 4 or gamma 4 PE constant region largely depends on the particular disease target. Preferably, depleting and non-depleting primatized IgG1 and IgG4 antibodies are created and tested against specific disease targets.

Given the described binding and functional properties of the subject monkey monoclonal antibodies, these anti-B7.1 monoclonal antibodies and primatized forms thereof should be well suited as therapeutic agents for blocking the B7:CD28 interaction thereby providing for immunosuppression. In particular, given their high affinity to B7.1 antigen and ability to block B cell/T cell interactions as measured by IL-2 production and tritiated thymidine uptake in mixed lymphocyte culture as well as their ability to effectively inhibit antigen driven responses in donor spleen cell cultures as shown by reduced antigen specific IgG responses, IL-2 production and cell proliferation, these monkey monoclonal antibodies and primatized forms thereof should function as effective immunosuppressants which modulate the B7:CD28 pathway. This is significant for the treatment of many diseases wherein immunosuppression is therapeutically desirable, e.g., autoimmune diseases, to inhibit undesirable antigen specific IgG responses, and also for prevention of organ rejection and graft-versus-host disease. Essentially, the subject antibodies will be useful in treating any disease wherein suppression of the B7:CD28 pathway is therapeutically desirable.

Key therapeutic indications for the subject anti-B7.1 antibodies include, by way of example, autoimmune diseases such as idiopathic thrombocytopenia purpura (ITP), systemic lupus erythematosus (SLE), type 1 diabetes mellitus, multiple sclerosis, aplastic anemia, psoriasis, allergy, inflammatory bile disease and rheumatoid arthritis.

Another significant therapeutic indication of the subject anti-B7.1 antibodies is for prevention of graft-versus-host-disease (GVHD) during organ transplant and bone marrow transplant (BMT). The subject antibodies may be used to induce host tolerance to donor-specific alloantigens and thereby facilitate engraftment and reduce the incidence of graft rejection. It has been shown in a murine model of allogeneic cardiac transplantation that intravenous administration of CTLA4-Ig can result in immunosuppression or even induction of tolerance to alloantigen. (Lin et al, *J. Exp. Med.* 178:1801, 1993; Torka et al, *Proc. Natl. Acad. Sci., USA* 89:11102, 1992). It is expected that the subject primatized anti-B7.1 antibodies will exhibit similar or greater activity.

Antibodies produced in the manner described above, or by equivalent techniques, can be purified by a combination of affinity and size exclusion chromatography for characterization in functional biological assays. These assays include determination of specificity and binding affinity as well as effector function associated with the expressed isotype, e.g., ADCC, or complement fixation. Such antibodies may be used as passive or active therapeutic agents against a number of human diseases, including B cell lymphoma, infectious diseases including viral diseases such as HIV/AIDS, autoimmune and inflammatory diseases, and transplantation. The antibodies can be used either in their native form, or as part of an antibody/chelate, antibody/drug or antibody/toxin complex. Additionally, whole antibodies or antibody fragments ($Fab_2$, Fab, Fv) may be used as imaging reagents or as potential vaccines or immunogens in active immunotherapy for the generation of anti-idiotypic responses.

The amount of antibody useful to produce a therapeutic effect can be determined by standard techniques well known to those of ordinary skill in the art. The antibodies will generally be provided by standard technique within a

pharmaceutically acceptable buffer, and may be administered by any desired route. Because of the efficacy of the presently claimed antibodies and their tolerance by humans it is possible to administer these antibodies repetitively in order to combat various diseases or disease states within a human.

The anti-B7.1 and or B7.2 antibodies (or fragments thereof) of this invention are useful for inducing immunosuppression, i.e., inducing a suppression of a human's or animal's immune system. Also, the invention relates to the use of antibodies specific to B7 antigen, e.g. B7.1 and/or B7.2 antigen, for inducing apoptosis of B7 antigen expressing cells, e.g. B cells, and the treatment of any condition wherein apoptosis of B7 antigen expressing cells is therapeutically beneficial. Examples of such conditions include those involving B cell tumors and cancers such as B cell lymphomas and leukemias. Examples of B cell lymphomas and leukemia suitable for treatment include Hodgkin's disease (all forms, e.g., relapsed Hodgkin's disease, resistant Hodgkin's disease) non-Hodgkin's lymphomas (low grade, intermediate grade, high grade, and other types). Examples include small lymphocytic/B cell chronic lymphocytic leukemia (SLL/B-CLL), lymhoplasmacytoid lymphoma (LPL), mantle cell lymphoma (MCL), follicular lymphoma (FL), diffuse large cell lymphoma (DLCL), Burkitt's lymphoma (BL), AIDS- related lymphomas, monocytic B cell lymphoma, angioimmunoblastic lymphoadenopathy, small lymphocytic, follicular, diffuse large cell, diffuse small cleaved cell, large cell immunoblastic lymphoblastoma, small, non-cleaved, Burkitt's and non-Burkitt's, follicular, predominantly large cell; follicular, predominantly small cleaved cell; and follicular, mixed small cleaved and large cell lymphomas. Other types of lymphoma classifications include immunocytomal Waldenstrom's MALT-type/monocytoid B cell, mantle cell lymphoma B-CLL/SLL, diffuse large B-cell lymphoma, follicular lymphoma, and precursor B-LBL. As noted, B cell malignancies further include especially leukemias such as ALL-L3 (Burkitt's type leukemia), chronic lymphocytic leukemia (CLL), chronic leukocytic leukemia, acute myelogenous leukemia, acute lymphoblastic leukemia, chronic lymphocytic leukemia, chronic myelogenous leukemia, lymphoblastic leukemia, lymphocytic leukemia, monocytic leukemia, myelogenous leukemia, and promyelocytic leukemia and monocytic cell leukemias.

Also, the use of such apoptosis inducing antibodies may be used in conjunction with other treatments that may induce or promote apoptosis such as chemotherapeutics, radioimmunotherapy, and antisense therapy. Examples of suitable chemotherapeutics include alkylating agents such as thiotepa and cyclosphosphamide (CYTOXAN™); alkyl sulfonates such as busulfan, improsulfan and piposulfan; aziridines such as benzodopa, carboquone, meturedopa, and uredopa; ethylenimines and methylamelamines including altretamine, triethylenemelamine, trietylenephosphoramide, triethylenethiophosphaoramide and trimethylolomelamime nitrogen mustards such as chiorambucil, chlornaphazine, cholophosphamide, estramustine, ifosfamide, mechlorethamine, mechlorethamine oxide hydrochloride, melphalan, novembichin, phenesterine, prednimustine, trofosfamide, uracil mustard; nitrosureas such as carmustine, chlorozotocin, fotemustine, lomustine, nimustine, ranimustine; antibiotics such as aclacinomysins, actinomycin, authramycin, azaserine, bleomycins, cactinomycin, calicheamicin, carabicin, carminomycin, carzinophilin, chromomycins, dactinomycin, daunorubicin, detorubicin, 6-diazo-5-oxo-L-norleucine, doxorubicin, epirubicin, esorubicin, idarubicin, marcellomycin, mitomycins, mycophenolic acid, nogalamycin, olivomycins, peplomycin, potfiromycin, puromycin, quelamycin, rodorubicin, streptonigrin, streptozocin, tubercidin, ubenimex, zinostatin, zorubicin; anti-metabolites such as methotrexate and 5-fluorouracil (5-FU); folic acid analogues such as denopterin, methotrexate, pteropterin, trimetrexate; purine analogs such as fludarabine, 6-mercaptopurine, thiamiprine, thioguanine; pyrimidine analogs such as ancitabine, azacitidine, 6-azauridine, carmofur, cytarabine, dideoxyuridine, doxifluridine, enocitabine, floxuridine, 5-FU; androgens such as calusterone, dromostanolone propionate, epitiostanol, mepitiostane, testolactone; anti-adrenals such as aminoglutethimide, mitotane, trilostane; folic acid replenisher such as frolinic acid; aceglatone; aldophosphamide glycoside; aminolevulinic acid; amsacrine; bestrabucil; bisantrene; edatraxate; defofamine; demecolcine; diaziquone; elfornithine; elliptinium acetate; etoglucid; gallium nitrate; hydroxyurea; lentinan; lonidamine; mitoguazone; mitoxantrone; mopidamol; nitracrine; pentostatin; phenamet; pirarubicin; podophyllinic acid; 2-ethylhydrazide; procarbazine; PSK®; razoxane; sizofiran; spirogermanium; tenuazonic acid; triaziquone; 2,

2',2"-trichlorotriethylamine; urethan; vindesine; dacarbazine; mannomustine; mitobronitol; mitolactol; pipobroman; gacytosine; arabinoside ("Ara-C"); cyclophosphamide; thiotepa; taxoids, e.g. paclitaxel (TAXOL®, Bristol-Myers Squibb Oncology, Princeton, NJ) and doxetaxel (Taxotere, Rhone-Poulenc Rorer, Antony, France); chlorambucil; gemcitabine; 6-thioguanine; mercaptopurine; methotrexate; platinum analogs such as cisplatin and carboplatin; vinblastine; platinum; etoposide (VP-16); ifosfamide; mitomycin C; mitoxantrone; vincristine; vinorelbine; navelbine; novantrone; teniposide; daunomycin; aminopterin; xeloda; ibandronate; CPT11; topoisomerase inhibitor RFS 2000; difluoromethylornithine (DMFO); retinoic acid; esperamicins; capecitabine; and pharmaceutically acceptable salts, acids or derivatives of any of the above. Also included in this definition are anti-hormonal agents that act to regulate or inhibit hormone action on tumors such as anti-estrogens including for example tamoxifen, raloxifene, aromatase inhibiting 4(5)-imidazoles, 4-hydroxytamoxifen, trioxifene, keoxifene, LY117018, onapristone, and toremifene (Fareston); and antiandrogens such as flutamide, nilutamide, bicalutamide, leuprolide, and goserelin; and pharmaceutically acceptable salts, acids or derivatives of any of the above. A particularly preferred chemotherapeutic is adriamycin, as IDEC-114 (anti-B7.1 antibody exemplified herein) potentiates apoptosis of lymphoma cells in combination therewith.

This invention therefore relates to a method of prophylactically or therapeutically inducing immunosuppression in a human or other animal in need thereof by administering an effective, non-toxic amount of such an antibody of this invention to such human or other animal.

The ability of the compounds of this invention to induce immunosuppression has been demonstrated in standard tests used for this purpose, for example, a mixed lymphocyte reaction test or a test measuring inhibition of T-cell proliferation measured by thymidine uptake.

For example, *in vitro* assays were conducted that measured cell growth and activating cytokines produced in response to co-stimulatory signals that activate CD4+ T cells. The production and secretion of these cytokines occurs naturally in T cells under conditions where a primary and secondary signal is generated through

interactions between T cells and antigen presenting cells. Normally a primary signal is initiated through interaction of a antigen specific T cell receptor and MHC Class II molecules bearing the specific antigen on antigen presenting cells. A secondary or co-stimulatory signal is required to obtain maximal activation of T cells. Several T cell co-stimulatory receptors have been identified that drive the production of various cytokines, and up-regulate other cell surface receptors that function in growth and differentiation of T cells and hematopoietic accessory cells. Some of the known signaling T cell co-stimulatory receptors are CD28, CD11, CD54 and CD40L. Sustained adhesion and prolonged interactions through these cell surface molecules result in secretion of IL-2 and various secondary inflammatory cytokines that control numerous immuno-regulatory functions. The study of T cell interactions can be complex due to the presence of numerous accessory cell types capable of mediating redundant or interdependent co-stimulatory effects.

The ability of antibodies according to the invention to induce apoptosis is evidenced by in vitro capsase induction assays and may be confirmed by other apoptosis assays.

The CD28/B7 receptor ligand interaction is considered to be the key secondary response element between antigen presenting cells and CD4+ helper T cells in the immune response cascade. After a primary signal is generated between antigen specific T cell receptors and antigen/MHC class II complexes, two types of B7 molecules, B7-1 (CD80) and B7-2, (CD86) are up-regulated and establish a membrane signaling event through binding to CD28 receptor. These signals drive the gene expression of various cytokines beginning with the production of IL-2. The detection of secreted IL-2, cell proliferation and various cell surface activation markers including the receptor for IL-2 are clear indicators that co-stimulation has occurred and cells are beginning to divide and differentiate to maturity. T cells may be influenced or driven down different maturation pathways depending on many complex internal and external factors through mechanisms that are poorly understood. The CD28/B7 interaction was first identified as an adhesion event when a B7 specific antibody was identified that blocked adhesion between B and T cell types. CD28 is known to affect *in vivo* immune responses by functioning both as a cell adhesion

molecule linking B and T lymphocytes and as the surface component of a novel signal transduction pathway (June et al. 1990, *Immunology Today*, 11: 211-216). As a result, several monoclonal antibodies that recognize either CD28 or B7 antigen, e.g. B7.1 and B7.2, are capable of blocking both adhesion and signaling events. Blocking of either event would lead directly or indirectly to reduced signaling through the CD28 receptor and would result in reduced IL-2 production, proliferation and the appearance of secondary cytokines.

More specifically, the present inventors have isolated certain novel antibodies, the activity of which apparently does not involve directly blocking of signal transduction as demonstrated through the use of CTLA-4Ig, a soluble receptor fusion protein that co-recognizes both B7 receptors. Evidence is provided herein that a primatized antibody according to the invention, referred to as IDEC- 114 blocks adhesion of antigen presenting cells to T cells thereby blocking an upstream event prior to signaling that under certain conditions, possibly related to B7 receptor density, is capable of influencing T cell activation. Evidence is provided through use of an *in vitro* assay that establishes distinct differences between the mechanism of action of IDEC- 114 and other anti-CD80 antibodies as well as CTLA-4Ig. The *in vitro* assay employed in these experiments was designed to reduce the number of complex interactions provided by accessory cells, by using a purified CD4+ T cell population and replacing accessory cells with a non-cellular co-stimulatory system. This cell activating system obviates the need for antigen presenting cells by using latex micospheres containing immobilized antibody to the CD3 antigen to deliver a suboptimal primary signal to the T cell. This system when presented along with B7, e.g. B7.1 (CD80) antigen and/or B7.2 (CD86) antigen, co-stimulatory ligand provides a very potent signal through the CD28 receptor that initiates gene expression resulting in production of IL-2, T cell growth and other pro-inflammatory cytokines.

The fact that the antibodies of this invention have utility in inducing immunosuppression indicates that they should be useful in the treatment or prevention of resistance to or rejection of transplanted organs or tissues (e.g., kidney, heart, lung, bone marrow, skin, cornea, etc.); the treatment or prevention of autoimmune, inflammatory, proliferative and hyperproliferative diseases, and of cutaneous

manifestations of immunologically medicated diseases (e.g., rheumatoid arthritis, lupus erythematosus, systemic lupus erythematosus, Hashimotos thyroiditis, multiple sclerosis, myasthenia gravis, type 1 diabetes, uveitis, nephrotic syndrome, psoriasis, atopical dermatitis, contact dermatitis and further eczematous dermatitides, seborrheic dermatitis, Lichen planus, Pemplugus, bullous pemphigus, Epidermolysis bullosa, urticaria, angioedemas, vasculitides, erythema, cutaneous eosinophilias, Alopecia areata, etc.); the treatment of reversible obstructive airways disease, intestinal inflammations and allergies (e.g., inflammatory bile disease, Coeliac disease, proctitis, eosinophilia gastroenteritis, mastocytosis, Crohn's disease and ulcerative colitis), food-related allergies (e.g., migraine, rhinitis and eczema), and other types of allergies. Also, as noted previously, antibodies according to the invention may be used in therapies wherein apoptosis of B7 expressing cells is therapeutically beneficial such as cancers characeterized by cancerous B cells, or cancers having an adverse B cell involvement. It has been reported, e.g. that B cells may promote the growth and/or metastasis of some cancers (not characterized by cancerous B cells), including some solid tumor types.

Also, the subject antibodies may promote apoptosis of other agents such as chemotherapeutics, antisense oligos, and radiotherapeutics.

One skilled in the art will be able, by routine experimentation, to determine what an effective, non-toxic amount of antibody will be for the purpose of inducing immunosuppression. Generally, however, an effective dosage will be in the range of about 0.05 to 100 milligrams per kilogram body weight per day.

The antibodies (or fragments thereof) of this invention should also be useful for treating tumors in a mammal. More specifically, they should be useful for reducing tumor size, inhibiting tumor growth and/or prolonging the survival time of tumor-bearing animals. Accordingly, this invention also relates to a method of treating tumors, e.g. those associated with B cell lymphomas, in a human or other animal by administering to such human or animal an effective, non-toxic amount of an antibody. One skilled in the art would be able, by routine experimentation, to determine what an effective, non-toxic amount of anti-B7 antibody would be for the purpose of treating carcinogenic tumors. Generally, however, an effective dosage is

expected to be in the range of about 0.05 to 100 milligrams per kilogram body weight per day.

The antibodies of the invention may be administered to a human or other animal in accordance with the aforementioned methods of treatment in an amount sufficient to produce such effect to a therapeutic or prophylactic degree. Such antibodies of the invention can be administered to such human or other animal in a conventional dosage form prepared by combining the antibody of the invention with a conventional pharmaceutically acceptable carrier or diluent according to known techniques. It will be recognized by one of skill in the art that the form and character of the pharmaceutically acceptable carrier or diluent is dictated by the amount of active ingredient with which it is to be combined, the route of administration and other well-known variables.

The route of administration of the antibody (or fragment thereof) of the invention include, by way of example, oral, parenteral, inhalation and topical. The term parenteral as used herein includes intravenous, intraperitoneal, intramuscular, subcutaneous, rectal or vaginal administration. The subcutaneous and intramuscular forms of parenteral administration are generally preferred.

The daily parenteral and oral dosage regimens for employing compounds of the invention to prophylactically or therapeutically induce immunosuppression, or to therapeutically treat carcinogenic tumors will generally be in the range of about 0.05 to 100, but preferably about 0.5 to 10, milligrams per kilogram body weight per day.

The antibodies of the invention may also be administered by inhalation. By "inhalation" is meant intranasal and oral inhalation administration. Appropriate dosage forms for such administration, such as an aerosol formulation or a metered dose inhaler, may be prepared by conventional techniques. The preferred dosage amount of a compound of the invention to be employed is generally within the range of about 10 to 100 milligrams.

The antibodies of the invention may also be administered topically. By topical administration is meant non-systemic administration and includes the application of an antibody (or fragment thereof) compound of the invention externally to the epidermis, to the buccal cavity and instillation of such an antibody into the ear, eye

and nose, and where it does not significantly enter the blood stream. By systemic administration is meant oral, intravenous, intraperitoneal and intramuscular administration. The amount of an antibody required for therapeutic or prophylactic effect will, of course, vary with the antibody chosen, the nature and severity of the condition being treated and the animal undergoing treatment, and is ultimately at the discretion of the physician. A suitable topical dose of an antibody of the invention will generally be within the range of about 1 to 100 milligrams per kilogram body weight daily.

**Formulations**

While it is possible for an antibody or fragment thereof to be administered alone, it is preferable to present it as a pharmaceutical formulation. The active ingredient may comprise, for topical administration, from 0.001% to 10% w/w, e.g., from 1% to 2% by weight of the formulation, although it may comprise as much as 10% w/w but preferably not in excess of 5% w/w and more preferably from 0.1% to 1% w/w of the formulation.

The topical formulations of the present invention, comprise an active ingredient together with one or more acceptable carrier(s) therefor and optionally any other therapeutic ingredients(s). The carrier(s) must be "acceptable" in the sense of being compatible with the other ingredients of the formulation and not deleterious to the recipient thereof.

Formulations suitable for topical administration include liquid or semi-liquid preparations suitable for penetration through the skin to the site of where treatment is required, such as liniments, lotions, creams, ointments or pastes, and drops suitable for administration to the eye, ear or nose.

Drops according to the present invention may comprise sterile aqueous or oily solutions or suspensions and may be prepared by dissolving the active ingredient in a suitable aqueous solution of a bactericidal and/or fungicidal agent and/or any other suitable preservative, and preferably including a surface active agent. The resulting solution may then be clarified by filtration, transferred to a suitable container which is then sealed and sterilized by autoclaving or maintaining at 90°-100°C for half an hour. Alternatively, the solution may be sterilized by filtration and transferred to the

container by an aseptic technique. Examples of bactericidal and fungicidal agents suitable for inclusion in the drops are phenylmercuric nitrate or acetate (0.002%), benzalkonium chloride (0.01%) and chlorhexidine acetate (0.01%). Suitable solvents for the preparation of an oily solution include glycerol, diluted alcohol and propylene glycol.

Lotions according to the present invention include those suitable for application to the skin or eye. An eye lotion may comprise a sterile aqueous solution optionally containing a bactericide and may be prepared by methods similar to those for the preparation of drops. Lotions or liniments for application to the skin may also include an agent to hasten drying and to cool the skin, such as an alcohol or acetone, and/or a moisturizer such as glycerol or an oil such as castor oil or arachis oil.

Creams, ointments or pastes according to the present invention are semi-solid formulations of the active ingredient for external application. They may be made by mixing the active ingredient in finely-divided or powdered form, alone or in solution or suspension in an aqueous or non-aqueous fluid, with the aid of suitable machinery, with a greasy or non-greasy basis. The basis may comprise hydrocarbons such as hard, soft or liquid paraffin, glycerol, beeswax, a metallic soap; a mucilage; an oil of natural origin such as almond, corn, arachis, castor or olive oil; wool fat or its derivatives, or a fatty acid such as stearic or oleic acid together with an alcohol such as propylene glycol or macrogols. The formulation may incorporate any suitable surface active agent such as an anionic, cationic or non-ionic surface active such as sorbitan esters or polyoxyethylene derivatives thereof. Suspending agents such as natural gums, cellulose derivatives or inorganic materials such as silicaceous silicas, and other ingredients such as lanolin, may also be included.

The subject anti-B7.1 antibodies or fragments thereof may also be administered in combination with other moieties which modulate the B7:CD28 pathway. Such moieties include, by way of example, cytokines such as IL-7 and IL-10, CTLA4-Ig, soluble CTLA-4 and anti-CD28 antibodies and fragments thereof. Also, the subject antibodies may be administered in combination with other immunosuppressants. Such immunosuppressants include small molecules such as cyclosporin A (CSA) and FK506; monoclonal antibodies such as anti-tumor necrosis

factor a (anti-TNFa), anti-CD54, anti-CD11, anti-CD11a, and anti-IL-1; and, other soluble receptors such as rTNFa and rIL-1.

It will be recognized by one of skill in the art that the optimal quantity and spacing of individual dosages of an antibody or fragment thereof of the invention will be determined by the nature and extent of the condition being treated, the form, route and site of administration, and the particular animal being treated, and that such optimums can be determined by conventional techniques. It will also be appreciated by one of skill in the art that the optimal course of treatment, i.e., the number of doses of an antibody or fragment thereof of the invention given per day for a defined number of days, can be ascertained by those skilled in the art using conventional course of treatment determination tests.

Without further elaboration, it is believed that one skilled in the art can, using the preceding description, utilize the present invention to its fullest extent. The following formulations are, therefore, to be construed as merely illustrative embodiments and not a limitation of the scope of the present invention in any way.

**Capsule Composition**

A pharmaceutical composition of this invention in the form of a capsule is prepared by filling a standard two-piece hard gelatin capsule with 50 mg. of an antibody or fragment thereof of the invention, in powdered form, 100 mg. of lactose, 32 mg. of talc and 8 mg. of magnesium stearate.

**Injectable Parenteral Composition**

A pharmaceutical composition of this invention in a form suitable for administration by injection is prepared by stirring 1.5% by weight of an antibody or fragment thereof of the invention in 10% by volume propylene glycol and water. The solution is sterilized by filtration.

**Ointment Composition**

Antibody or fragment thereof of the invention 1.0 g.

White soft paraffin to 100.0 g.

The antibody or fragment thereof of the invention is dispersed in a small volume of the vehicle to produce a smooth, homogeneous product. Collapsible metal tubes are then filled with the dispersion.

**Topical Cream Composition**

Antibody or fragment thereof of the invention 1.0 g.

Polawax GP 200 20.0 g.

Lanolin Anhydrous 2.0 g.

White Beeswax 2.5 g.

Methyl hydroxybenzoate 0.1 g.

Distilled Water to 100.0 g.

The polawax, beeswax and lanolin are heated together at 60°C. A solution of methyl hydroxybenzoate is added and homogenization is achieved using high speed stirring. The temperature is then allowed to fall to 50°C. The antibody or fragment thereof of the invention is then added and dispersed throughout, and the composition is allowed to cool with slow speed stirring.

**Topical Lotion Composition**

Antibody or fragment thereof of the invention 1.0 g.

Sorbitan Monolaurate 0.6 g.

Polysorbate 20 0.6 g.

Cetostearyl Alcohol 1.2 g.

Glycerin 6.0 g.

Methyl Hydroxybenzoate 0.2 g.

Purified Water B.P. to 100-00 ml. (B.P. = British Pharmacopeia)

The methyl hydroxybenzoate and glycerin are dissolved in 70 ml. of the water at 75°C. The sorbitan monolaurate, polysorbate 20 and cetostearyl alcohol are melted together at 75°C and added to the aqueous solution. The resulting emulsion is homogenized, allowed to cool with continuous stirring and the antibody or fragment thereof of the invention is added as a suspension in the remaining water. The whole suspension is stirred until homogenized.

**Eye Drop Composition**

Antibody or fragment thereof of the invention 0.5 g.

Methyl Hydroxybenzoate 0.01 g.

Propyl Hydroxybenzoate 0.04 g.

Purified Water B.P. to 100-00 ml.

The methyl and propyl hydroxybenzoates are dissolved in 70 ml. purified water at 75°C and the resulting solution is allowed to cool. The antibody or fragment thereof of the invention is then added, and the solution is sterilized by filtration through a membrane filter (0.022 μm pore size), and packed aseptically into suitable sterile containers.

**Composition for Administration by Inhalation**

For an aerosol container with a capacity of 15-20 ml: mix 10 mg. of an antibody or fragment thereof of the invention with 0.2-0.5% of a lubricating agent, such as polysorbate 85 or oleic acid, and disperse such mixture in a propellant, such as freon, preferably in a combination of (1,2 dichlorotetrafluoroethane) and difluorochloro-methane and put into an appropriate aerosol container adapted for either intranasal or oral inhalation administration.

**Composition for Administration by Inhalation**

For an aerosol container with a capacity of 15-20 ml: dissolve 10 mg. of an antibody or fragment thereof of the invention in ethanol (6-8 ml.), add 0.1-0.2% of a lubricating agent, such as polysorbate 85 or oleic acid; and disperse such in a propellant, such as freon, preferably in combination of (1.2 dichlorotetra-fluoroethane) and difluorochloromethane, and put into an appropriate aerosol container adapted for either intranasal or oral inhalation administration.

The antibodies and pharmaceutical compositions of the invention are particularly useful for parenteral administration, i.e., subcutaneously, intramuscularly or intravenously. The compositions for parenteral administration will commonly comprise a solution of an antibody or fragment thereof of the invention or a cocktail thereof dissolved in an acceptable carrier, preferably an aqueous carrier. A variety of aqueous carriers may be employed, e.g., water, buffered water, 0.4% saline, 0.3% glycine, and the like. These solutions are sterile and generally free of particulate matter. These solutions may be sterilized by conventional, well-known sterilization techniques. The compositions may contain pharmaceutically acceptable auxiliary substances as required to approximate physiological conditions such as pH adjusting and buffering agents, etc. The concentration of the antibody or fragment thereof of the invention in such pharmaceutical formulation can vary widely, i.e., from less than

about 0.5%, usually at or at least about 1% to as much as 15 or 20% by weight, and will be selected primarily based on fluid volumes, viscosities, etc., according to the particular mode of administration selected.

Thus, a pharmaceutical composition of the invention for intramuscular injection could be prepared to contain 1 Ml sterile buffered water, and 50 mg. of an antibody or fragment thereof of the invention. Similarly, a pharmaceutical composition of the invention for intravenous infusion could be made up to contain 250 ml. of sterile Ringer's solution, and 150 mg. of an antibody or fragment thereof of the invention. Actual methods for preparing parenterally administrable compositions are well known or will be apparent to those skilled in the art, and are described in more detail in, for example, *Remington's Pharmaceutical Science*, 15th ed., Mack Publishing Company, Easton, Pennsylvania, hereby incorporated by reference herein.

The antibodies (or fragments thereof) of the invention can be lyophilized for storage and reconstituted in a suitable carrier prior to use. This technique has been shown to be effective with conventional immune globulins and art-known lyophilization and reconstitution techniques can be employed.

Depending on the intended result, the pharmaceutical composition of the invention can be administered for prophylactic and/or therapeutic treatments. In therapeutic application, compositions are administered to a patient already suffering from a disease, in an amount sufficient to cure or at least partially arrest the disease and its complications. In prophylactic applications, compositions containing the present antibodies or a cocktail thereof are administered to a patient not already in a disease state to enhance the patient's resistance.

Single or multiple administrations of the pharmaceutical compositions can be carried out with dose levels and pattern being selected by the treating physician. In any event, the pharmaceutical composition of the invention should provide a quantity of the altered antibodies (or fragments thereof) of the invention sufficient to effectively treat the patient.

It should also be noted that the antibodies of this invention may be used for the design and synthesis of either peptide or non-peptide compounds (mimetics) which

would be useful in the same therapy as the antibody. See, e.g., Saragovi et al., *Science*, 253, 792-795 (1991).

To further illustrate the invention, the following examples are provided. These examples are not intended, nor are they to be construed, as further limiting the invention.

## EXAMPLE 1

Recombinant immunoglobulin libraries displayed on the surface of filamentous phage were first described by McCafferty et al, Nature, 348:552-554, 1990 and Barbas et al, *Proc. Natl. Acad. Sci., USA* 88:7978-7982, 1991. Using this technology, high affinity antibodies have been isolated from immune human recombinant libraries (Barbas et al, *Proc. Natl. Acad. Sci., USA* 589:10164-10168, 1992). Although the phage display concept used is substantially similar to that described by Barbas, 1991, Id. the technique has been modified by the substitution of a unique vector for monkey libraries to reduce the possibility of recombination and improve stability. This vector, pMS, Figure 1 contains a single lac promoter/operator for efficient transcription and translation of polycistronic heavy and light chain monkey DNA. This vector contains two different leader sequences, the omp A (Movva et al, *J. Biol. Chem.* 255: 27-29 (1980), for the light chain and the pel B (Lei, *J. Bact.*, 4379-109:4383 (1987) for the heavy chain Fd. Both leader sequences are translated into hydrophobic signal peptides that direct the secretion of the heavy and light chain cloned products into the periplasmic space. In the oxidative environment of the periplasm, the two chains fold and disulfide bonds form to create stable Fab fragments. We derived the backbone of the vector from the phagemid bluescript. (Stratagene, La Jolla, CA). It contains the gene for the enzyme beta-lactamase that confers ampicillin (carbenicillin) resistance to bacteria that harbor pMS DNA. We also derived, from bluescript, the origin of replication of the multicopy plasmid ColEl and the origin of replication of the filamentous bacteriophage f1. The origin of replication of phage fl (the so-called intragenic region), signals the initiation of synthesis of single stranded pMS DNA, the initiation of capsid formation and the termination of RNA synthesis by viral enzymes. The replication and assembly of

pMS DNA strands into phage particles requires viral proteins that must be provided by a helper phage. We have used helper phage VCSM13 which is particularly suited for this, since it also contains a gene coding for kanamycin resistance. Bacteria infected with VCSM13 and pMS can be selected by adding both kanamycin and carbenicillin to the growth medium. The bacteria will ultimately produce filamentous phage particles containing either pMS or VCSM13 genomes. Packaging of the helper phage is less efficient than that of pMS, resulting in a mixed phage population that contains predominately recombinant pMS phages. The ends of the phage pick up minor coat proteins specific to each end. Of particular interest here is the gene III product which is present in three to five copies at one end of the phage. The gene III product is 406 amino acid residues and is required for phage infection of *E. coli* via the F pili. The first two domains of the heavy chain, the variable and the CH1 domain, are fused to the carboxy-terminal half of the gene III protein. This recombinant pili protein, directed by the pel B leader, is secreted to the peroplasm where it accumulates and forms disulfide bonds with the light chain before it is incorporated in the coat of the phage. Also, another vector contains a FLAG sequence engineered downstream of the gene III. The FLAG is an 8 amino acid peptide expressed at the carboxy terminal of the Fd protein. We are using commercially available monoclonal anti-FLAG M2 for both purification and detection of phage Fab by ELISA (Brizzard, *Bio Techniques* 16(4):730-731 (1994)).

After constructing the vector pMS, we tested its ability to produce phage bound Fab using control antibody genes. We cloned an anti-tetanus toxoid antibody, (obtained from Dr. Carlos Barbas), into pMS and transformed XLI-blue. We co-infected our cells with VCSM13 and generated phage displaying the anti-tetanus toxoid antibody. We performed efficiency experiments where anti-tetanus toxoid phage were combined with phage beading an irrelevant antibody at 1:100,000. We performed three rounds of panning by applying 50 µl of the mixed phage to antigen (tetanus toxoid) coated polystyrene wells. Non-adherent phage were washed off and the adherent phage were eluted with acid. The eluted phage were used to infect a fresh aliquot of XL1Blue bacteria and helper phage was added. After overnight amplification, phage were prepared and again panned on antigen coated plates. After

three rounds of panning, we were able to show that we had successfully enriched for the anti-tetanus toxoid phage. The success of this technology also depends on the ability to prepare soluble Fabs for characterization of the final panned product. This was achieved by excising gene III from the pMS DNA using the restriction enzyme Nhe I followed by re-ligation. After the gene III was excised, the Fab was no longer displayed on the phage surface but accumulated in the piroplasmic space. Lysates were prepared from bacteria expressing soluble Fab and tested for antigen specificity using an ELISA. High levels of soluble Fab were detected.

In order to adapt phage display technology for use with macaque libraries, we developed specific primers for PCR amplifying monkey immunoglobulin genes. These were based on macaque sequences we obtained while developing the PRIMATIZED® antibody technology (*See*, U.S. Patent No. 5,658,570) and databases containing human sequences. (Kabat et al, (1991), "Sequences of Proteins of Immunological Interest," U.S. Dept. of Health and Human Services, National Institute of Health).

We developed three sets of primers to cover amplification of the macaque repertoire. Our first set of primers was designed for amplification of the heavy chain VH and CH1 (Fd) domains. It consisted of a 3' CH1 domain primer and six 5' VH family specific primers that bind in the framework 1 region. Our second set of primers, for amplifying the whole lambda chain, covers the many lambda chain subgroups. It consists of a 3' primer and three 5' degenerate primers that bind in the VL framework 1 region. Our third set of primers was designed for amplification of the kappa chain subgroups. It consists of one 3' primer and five VK framework 1 primers. Using each of these sets, PCR parameters were optimized to obtain strong enough signals from each primer pair so that ample material was available for cloning of the library. We recently created macaque combinatorial libraries in our pMS vector using these optimized PCR conditions. Bone marrow biopsies were taken from CD4 immune monkeys as the source of immunoglobulin RNA. The libraries contained approximately $10^6$ members and are currently being panned or specific binders on antigen coated wells.

## EXAMPLE 2

*Development of B7/CTLA-4 Reagents*

We have generated a number of reagents for the purpose of immunizing monkeys, developing binding and functional assays *in vitro*, screening heterohybridomas and panning phage libraries. Table 1 lists each reagent and its intended purpose. In the case of B7.1, RNA was extracted from SB cells and converted to cDNA using reverse transcriptase. The first strand cDNA was PCR amplified using B7.1 specific primers and cloned into IDEC's NEOSPLA mammalian expression vectors. CHO cells were transfected with B7.1 NEOSPLA DNA and clones expressing membrane associated B7.1 were identified. The B7.1 fusion protein was generated similarly, except that the PCR amplified B7.1 gene was cloned into a NEOSPLA cassette vector containing the human CH2 and CH3 immunoglobulin genes. CHO cells were transformed with the B7.1/Ig NEOSPLA DNA and stable clones secreting B7.1/Ig fusion protein were amplified. In general, the B7.2 and CTLA4 reagents were generated in the same manner, except that for B7.2 the RNA was isolated from human spleen cells that had been stimulated 24 hours with anti-Ig and IL-4, and for the CTLA4 constructs the gene source was PHA activated human T cells.

**TABLE 1**

| Reagent | Purpose | CHO Expressi n |
|---|---|---|
| Soluble B7.1 | Immunization, immunoassays | Yes |
| B7.1 Transfectant | Screening, ELISA | Yes |
| B7.1/Ig Fusion Protein | Inhibition studies, panning | Yes |
| B7.2 Transfectant | Screening, ELISA | Yes |
| B7.2/Ig Fusion Protein | Inhibition studies, panning | To be completed |
| CTLA4 Transfectant | Inhibition studies | To be completed |
| CTLA4/Ig | Inhibition studies | To be completed |

The availability of these reagents, together with monoclonal antibodies to B7.1 (L3074) (Becton Dickinson, 1994) and B7.2 (Fun-1 (Engel et al, Blood, 84, 1402-1407, (1994) and purified goat and rabbit antisera, specifically developed to detect monkey Fab fragments, facilitates identification of antibodies having the desired properties.

## EXAMPLE 3

*Generation of a Phage Display Library*

Recombinant phage display libraries are generated from B7.1 and B7.2 immune monkeys. Lymph node and bone marrow biopsies are performed 7-12 days after immunization to harvest RNA rich B cells and plasma cells. RNA is isolated from the lymphocytes using the method described by Chomczynski, *Anal. Biochem.*, 162(1), 156-159 (1987). RNA is converted to cDNA using an oligo dT primer and reverse transcriptase. The first strand cDNA is divided into aliquots and PCR amplified using the sets of kappa, lambda, and heavy chain Fd region primers described earlier and either Pfu polymerase (Stratagene, San Diego) or Taq polymerase (Promega, Madison). The heavy chain PCR amplified products are pooled, cut with Xho VSpe I restriction enzymes and cloned into the vector pMS. Subsequently, the light chain PCR products are pooled, cut with Sac I/Xba I restriction enzymes, and cloned to create the recombinant library. XLI-Blue *E. coli* is transformed with the library DNA and super-infected with VCSM13 to produce the phage displaying antibodies. The library is panned four rounds on polystyrene wells coated with B7.1 or B7.2 antigen. Individual phage clones from each round of panning are analyzed. The pMS vector DNA is isolated and the gene III excised. Soluble Fab fragments are generated and tested in ELISA for binding to B7.1 and B7.2.

## EXAMPLE 4

*Characterization of Phage Fab Fragments*

The monkey phage Fab fragments are characterized for their specificity and the ability to block B7.1-Ig and B7.2-Ig binding to CTLA-4-Ig or CTLA-4 transfected

cells. Phage fragments are also characterized for cross-reactivity after first panning for 4 rounds on the B7 species used for immunization in order to select for high affinity fragments. Fab fragments identified from four rounds of panning either on B7.1 or B7.2 antigen coated surfaces are scaled up by infection and grown in 24 hour fermentation cultures of E coli. Fragments are purified by Kodak FLAG binding to a anti-FLAG affinity column. Purified phage Fabs are tested for affinity by an ELISA based direct binding modified Scatchard analysis (Katoh et al, *J. Chem. BioEng.* 76:451-454 (1993)) using Goat anti-monkey Fab antibodies or anti-FLAG MAb conjugated with horseradish peroxidase. The anti-monkey Fab reagents will be absorbed against human heavy chain constant region Ig to remove any cross-reactivity to B7-Ig. Kd values are calculated for each fragment after measurements of direct binding to B7.1-Ig or B7.2-Ig coated plates.

## EXAMPLE 5

*Phage Fab Fragment Blocking of CTLA-4/B7 Binding*

Fab fragments most effectively blocking the binding of B7-Ig at the lowest concentrations are selected as lead candidates. Selections are made by competing off $^{125}$I-B7-Ig binding to CTLA-4-Ig or CTLA-4 transfected cells. Additional selection criteria include, blocking of mixed lymphocyte reaction (MLR), as measured by inhibiting 3H-thymidine uptake in responder cells (Azuma et al, *J. Exp. Med.* 177:845-850; Azuma et al, *Nature* 301:76-79 (1993)) and direct analysis of IL-2 production using IL-2 assay kits. The three or four candidates which are most effective in inhibiting of MLR and CTLA-4 binding assays are chosen for cloning into the above-described mammalian expression vector for transfection into CHO cells and expression of chimeric monkey/human antibodies.

## EXAMPLE 6

*Generation of Monkey Heterohybridomas*

Monkey heterohybridomas secreting monoclonal antibodies are generated from existing immunized animals whose sera tested positive for B7.1 and/or B7.2. Lymph node biopsies are taken from animals positive to either, or both, antigens. The

method of hybridoma production is similar to the established method used for the generation of monkey anti-CD4 antibodies (Newman, 1992 (*Id.*)). Monkeys with high serum titers will have sections of inguinal lymph nodes removed under anesthesia. Lymphocytes are washed from the tissue and fused with KH6/B5 heteromyeloma cells (Carrol et al, *J. Immunol. Meth.* 89:61-72 (1986)) using polyethylene glycol (PEG). Hybridomas are selected on H.A.T. media and stabilized by repeated subcloning in 96 well plates.

Monkey monoclonal antibodies specific for B7.1 antigen are screened for cross-reactivity to B7.2. Monkey anti-B7 antibodies will be characterized for blocking of B7/CTLA-4 binding using the $^{125}$I-B7-Ig binding assay. Inhibition of MLR by 3H-Thymidine uptake and direct measurement of IL-2 production is used to select three candidates. Two candidates will be brought forward in Phase II studies and expressed in CHO cells while repeating all functional studies. For the purposes of developing an animal model for *in vivo* pharmacology, anti-B7 antibodies will be tested on cells of several animal species. The establishment of an animal model will allow preclinical studies to be carried out for the selected clinical indication.

## EXAMPLE 7

As discussed *supra*, using the above heterohybridoma methods, 4 lead monkey anti-B7.1 antibodies have been identified: 16C10, 7B6, 7C10 and 20C9. These antibodies were characterized as follows.

Scatchard analysis showed that the apparent affinity constants (Kd) for the monkey antibodies binding to B7-Ig coated plates were approximated to be:

a: 7C10: $6.2 \times 10^{-9}$M

b: 16C10: $8.1 \times 10^{-9}$M

c: 7B6: $10.7 \times 10^{-9}$M

d: 20C9: $16.8 \times 10^{-9}$M

The antibodies were tested *in vitro* in a mixed lymphocyte reaction assay (MLR). The MLR showed that all 4 anti-B7.1 antibodies inhibit IL-2 production to different extents:

a: 7B6: 5.0 μg/Ml

b: 16C10: 0.1 μg/Ml

c: 20C9: 2.0 μg/Ml

d: 7C10: 5.0 μg/Ml

The monkey anti-B7.1 antibodies were tested for their ability to bind B7 on human peripheral blood lymphocytes (PBL). FACS analysis showed that all 4 monkey antibodies tested positive.

Monkey antibodies 16C10, 7B6, 7C10 and 20C9 were tested for C1q binding by FACS analysis. Results showed 7C10 monkey Ig had strong human C1q binding after incubating with B7.1 CHO-transfected cells. 16C10 was also positive, while 20C9 and 7B6 monkey antibodies were negative.

## EXAMPLE 8

Using the primatized antibody methodology incorporated by reference to commonly assigned U.S. Patent No. 5,658,570, and using the NEOSPLA vector system shown in Figure 2, the heavy and light variable domains of 7C10, 7B6 and 16C10 were cloned and primatized forms thereof have been synthesized in CHO cells using the NEOSPLA vector system. The amino acid and nucleic acid sequences for the primatized 7C10 light and heavy chain, 7B6 light and heavy chain, and 16C10 light and heavy chain are respectively shown in Figures 3a, 3b, 4a, 4b, 5a and 5b.

## EXAMPLE 9

*Confirming experiments on the non-cross-reactivity of the CTLA-4 and PRIMATIZED® antibody binding sites on B7.1.*

In competitive binding assays using biotinylated CTLA-4Ig (Figure 6), unlabeled primatized 16C10 (i.e., P16C10) was unable to block CTLA-4Ig binding to B7.1 transfected CHO cells. It can be seen that unlabeled CTLA-4Ig and unlabeled B7.1 effectively compete under these conditions.

In a second experiment using Biotinylated P16C10, the same conclusions can be made. In the experiment shown in Figure 7, binding of P16C10-Biotin is inhibited by both unlabeled P16C10 and B7.1Ig, but not by CTLA-4Ig. Although CTLA-4Ig is reported to be as much as 4-10 fold higher in affinity (Kd=0.4 nM; Morton et al., *J.*

*Immunol.* 156:1047-1054 (1996)), there is no significant inhibition of P16C10 binding even at CTLA-4Ig concentrations as high as 100 fold excess.

Similar results were obtained using the primatized antibody 7C10 (P7C10) when it was substituted for P16C10 in the experiments (data not provided).

5

**EXAMPLE 10**

*Comparing the ability of L307.4 and BB-1 mouse antibodies to bind to B7 CHO cells in the presence of CTLA-4Ig.*

The binding of L307.4 and BB-1 murine anti-B7 antibody in the presence of
10 CTLA-4Ig was studied in order to determine whether the mouse antibody binding sites overlapped with the CTLA-4 binding site. Competition assay experiments using P16C10-Biotin, L307.4-Biotin and CTLA-4Ig-Biotin were done to insure that affinity differences did not prevent detection of competitive binding. The results are shown in Figures 8 and 9.

15 The results of Figure 8 confirm earlier studies that the mouse antibody BB-1 does not compete with P16C10. These results also show that there is some cross-reactivity to L307.4 of approximately 50%. The results of Figure 8 confirm that BB-1 and L307.4 both compete with each other and that BB-1 completely blocks binding of CTLA-4Ig-Biotin to B7.1 transfected CHO cells. BB-1 does not significantly affect
20 P16C10 binding to B7.1 positive CHO cells.

The results shown in Figure 9 indicate better than 50% competition when CTLA-4Ig-Biotin is used in the binding experiment. Figure 9 shows that CTLA-4Ig-Biotin is effectively blocked by all B7.1 inhibitors except P16C10, therefore P16C10 recognizes a unique binding determinate on B7.1 which allows the normal CTLA-4
25 ligand binding in the generation of negative signals. Earlier functional studies (data not shown) suggest a weakened ability of L307.4 to block IL-2 production in allogeneic MLR, which correlates with the hypothesis that it may interfere with CTLA-4 negative signaling. It is not clear how many of the other murine antibodies reported in the literature give complete inhibition of CTLA-4 binding; however, this
30 issue may be important in defining the true functional mechanisms of B7.1 and B7.2 specific antibodies.

These results confirm earlier studies using B7-Ig in competition with P16C10-Biotin for binding to B7.1 transfected CHO cells. The studies also confirm earlier observations of no inhibition of the P16C10 by CTLA-4Ig. These results are highly suggestive that the primate antibodies are specific for a unique B7.1 epitope independent of the CTLA-4 binding site which interacts primarily with CD28. This type of interaction would provide a benefit, since it has the ability to block binding of B7.1 to CD28 receptors while still allowing the negative signaling function of CTLA-4 to occur uninhibited. This perceived interaction may lead to a down regulation of the overall T cell activation response regardless of the predominance of either Th1 or Th2 phenotypes.

Similar results were obtained using P7C10 when it was substituted for P16C10 in the experiments (data not provided).

## EXAMPLE 11

*Experiment demonstrating the ability of P16C10 to bind and block B7.1 interactions with CD28 receptor.*

An experiment to determine if P16C10 binding of B7.1 can block the interaction of B7.1 with CD28 was attempted by radiolabeling B7.1Ig with $^{125}I$, followed by competitive binding to CD28 positive non-activated peripheral blood T lymphocytes. The results shown in Figure 10 demonstrate that the radiolabeled B7.1Ig binds specifically to the T cells, as confirmed by inhibition with unlabeled B7.1Ig. The results also show that CTLA-4Ig, anti-CD28 and P16C10 are all capable of blocking this interaction. The results further confirm that P16C10 blocks binding of the CD28/B7 interaction with an $IC_{50}$ of < 1 ug/mL.

The above results were obtained under conditions where no membrane associated CTLA-4 was expressed (Linsley et al., *J. Exp. Med.* 173:721-730 (1991)) and confirmed by blocking with the anti-CD28 antibody.

Similar results were obtained using P7C10 when it was substituted for P16C10 in the experiments (data not provided).

## EXAMPLE 12

*IDEC-114 does not block IL-2 production in co-stimulated T cells.*

In an experiment, the results of which are contained in Figure 11, a sub-optimal primary signal was induced by attaching an anti-CD3 antibody and a soluble B7Ig fusion protein to covalently coupled protein-A latex microspheres. Initially, a 1:10 ratio of anti-CD3 to B7Ig was used which is a relatively high density of B7 co-stimulatory molecules that is several times greater than normal cells express based on the relative amounts of IL-2 that are typically produced. Purified CD4+ T cells obtained from blood bank donors and co-cultured the cells in presence or absence of soluble CD28:B7 inhibitors that included anti CD80 antibodies L307.4 and IDEC-114 and soluble CTLA-4Ig fusion protein were added at three concentrations ranging from 10 to 0. 1 μg/mL. Samples of tissue culture media were collected after 48 hours and the IL-2 cytokine present in the cultures was determined. The results show clearly that beads containing anti-CD3 alone and B7Ig alone produced little or no IL-2. By contrast, both anti-CD3 and B7Ig were present approximately 4500 pg/mL of IL-2 was produced. The results also revealed that both L307.4 and CTLA-4Ig completely inhibited the production of IL-2 at all concentrations where IDEC-114 had no effect. These results suggest that L307.4 and CTLA-4Ig regulate the activation of T cells by a similar mechanism that directly interferes with CD28 signaling to produce the activating cytokine IL-2 while IDEC-114 has no such functional property.

## EXAMPLE 13

*IDEC-114 does not block growth in co-stimulated T cells.*

The same cultures were analyzed for effect on cell growth and similar results to the effects on IL-2 production were obtained. As seen in Figure 12, L307.4 and CTLA-4Ig were equally effective in totally blocking cell proliferation as determined by uptake of radiolabeled thymidine. Under these same conditions, IDEC-114 had no effect on cell growth. These results further suggest that IDEC-114 is not directly regulating the growth and differentiation properties of CD4+ T cells by blocking the interaction between B7(CD80) and CD28 receptors, unlike other tested anti-B7 antibodies having different binding specifications.

## EXAMPLE 14

*IDEC-114 partially blocks IL-10 production in co-stimulated T cells.*

The same cultures were analyzed for the presence of the secondary TH2 cytokine IL-10. It was found that both L307.4 and CTLA-4 again completely blocked IL-10 production, whereas IDEC-114 only partially blocked IL-10 proeduction. As seen in Figure 3, L307.4 and CTLA-4Ig were about equally effective in blocking IL-10 production while IDEC-114 had a partial effect. The partial inhibition of IL-10 by IDEC-114 may be a function of its property of allowing negative signaling to occur in T cells by not interfering with the function of CTLA-4 expressed in T cells. CTLA-4 is upregulated in T cells during co-stimulation and is thought to provide a negative signal to T cells. These results further suggest that IDEC-114 is not regulating the cytokine producing properties of CD4+ T cells through the normal channels involving CD28 signal transduction.

## EXAMPLE 15

*IDEC-114 blocks IL-2 production in T cells co-stimulated with micro-beads containing reduced amounts of B7.*

In another experiment, the ratio of anti-CD3 to B7-Ig was adjusted on the stimulator beads from a 1:10 ratio to 8:1 or a reduction in B7 of about 80-fold with an 8-fold excess of anti-CD3. The production of IL-2 under these conditions is significantly reduced to typically less than 1000 pg/mL and is more in line with cultures stimulated with mismatched allotypes or CD80 transfected cells. Under these conditions (Figure 14), we observed near complete inhibition of IL-2 with CTLA-4Ig consistent with results obtained by beads with an anti-CD3/B7-Ig ratio of 1:10. However, with IDEC-114, we routinely observed significant inhibition of IL-2 (50-90%). We are also able to block IL-2 generated in cultures of mixed lymphocytes or when B7 transfected CHO cells are used as stimulators instead of microbeads.

These results suggest that IDEC-114 may function by interfering with adhesion and its effects may be facilitated by reduced expression or maintaining of a lower avidity form of CD80 during co-stimulation.

## EXAMPLE 16

An experiment was conducted to evaluate the potential ability of IDEC-114 to induce apoptosis of B7 antigen expressing cells, particularly SKW cells, a known human B cell lymphoma cell line. Whether apoptosis was induced was evaluated based on capsase levels in the presence or absence of IDEC-114 and a suitable control (irrelevant antibody). These experiments showed that IDEC-114 induced the expression of capsase relative to the control. As capsase induction is an indicator of apoptosis, these results suggest that anti-B7 antibodies according to the invention may be used to induce apoptosis of B7 antigen expressing cells, e.g. B cells, and preferably B cells associated with B cell related cancers and lymphomas.

*Analysis of Results.*

The T cell regulatory properties of IDEC-114 and CTLA-4Ig were compared in an *in vitro* co-stimulatory system that includes purified CD4+ helper T cells in the absence of accessory cells. In place of accessory antigen-presenting cells, Protein A coated latex microspheres and attached anti-CD3 and B7Ig fusion protein were used. When T-cells were incubated with beads that contained a 10-fold excess of B7 there was a strong co-stimulatory response as measured by IL-2, IL-10 and cell growth that was totally blocked by CTLA-4Ig and a commercially available anti-CD80 monoclonal antibody L307.4. By contrast IDEC-114 had no effect on IL-2 or cell growth but did partially inhibit IL-10 production. It appears that both CTLA-4 and L307.4 possess higher affinities to B7 antigen and that increasing the concentration of IDEC-114 in the cultures should result in the same effect. Based thereon, the affinities of CTLA-4Ig and IDEC-114 (Kd=4 nM) were compared by surface plasmon resonance. It was found that the affinity of CTLA-4Ig (Morten et al., 1996, *J. Immunol.* 156: 1047-1054) was approximately 10-fold higher (Kd=0.4nM). This assay was performed using as much as 1000-fold greater concentration of IDEC-114 with no effect on IL-2. Also, when T-cells were activated in cultures with beads containing a reduced content of B7 (anti-CD3/B7, 8:1), significant blocking of IL-2 production by both CTLA-4Ig and IDEC- 114 was observed. In the latter experiment the equivalent blocking ability of IDEC-114 required approximately 10-fold higher

concentration than CTLA-4Ig and was comparable to the difference between the affinities of the two. These results were interpreted by hypothesizing that reduced amounts of B7 on the beads may lead to a reduction in the forming of stable interactions with CD28. This low affinity state may somewhat resemble normal resting B cells. Therefore, with the reduced avidity for adhesion, IDEC-114 may bind to a remote site inducing a conformational change resulting in even lower affinity of CD80 for CD28.

Alternatively, antigen presenting cells that become activated may increase their surface density to the extent that the highly mobile B7 molecules more easily form homodimers. With respect thereto, it has been reported that monomeric forms of B7 have extremely low affinity and fast off-rate kinetics (van der Merwe, et al. 1997, J. Exp. Med., 185: 393-403) and that homodimeric forms can have up to 500-fold higher affinity. A higher affinity form would understandably facilitate cluster or patch formation leading to a more stable receptor ligand complex. Consequently, IDEC-114 may bind to a remote site that could restrict the association of neighboring CD80 molecules and reduce or limit the amount of dimerization effectively limiting the adhesion complex formation.

The observed results suggest that primatized antibodies having the novel binding properties disclosed herein do not influence the regulation of T cells, unlike prior anti-B7.1 antibodies. It is hypothesized, based on these results, that the antibodies of the invention, such as IDEC - 114, bind to a unique site on CD80 expressed on antigen presenting cells which prevents the association of CD80 receptors from forming a higher affinity interaction with CD28 receptors on T cells. This would generate a weaker signal through CD28 that under certain conditions could not be overcome by the upregulation of more B7 ligand. However, these same results do not preclude the ability of IDEC-114 to function in other types of immune regulatory mechanisms occurring *in vivo* where the presence of NK cells and macrophages may contribute to killing of B cells or activated T cells through Fc and complement mediated effects.

It is anticipated that these primatized antibodies, given their probable low antigenicity and human effector function, will be well suited as therapeutics. In this

regard, it has been shown that primatized 16C10 (IDEC - 114) exhibits human Clq binding.

Those skilled in the art will recognize or be able to ascertain using no more than routine experimentation many equivalents to the specific embodiments of the invention described herein. Such equivalents are intended to be embraced by the following claims.

**WHAT IS CLAIMED IS:**

1. A method of using a monoclonal antibody which specifically binds to B7.1 antigen (CD80) and/or B7.2 antigen (CD86) for inducing the apoptosis of B7+ cells.

2. The method of Claim 1, wherein the B7+ cells are B cells.

3. The method of Claim 2, wherein said antibody selectively inhibits the interaction of B and T cells via the CD28/B7.1 pathway.

4. The method of Claim 1, wherein said antibody is capable of inhibiting *in vitro* the production of IL-2 by T lymphocytes.

5. The method of Claim 4, wherein said antibody is capable of inhibiting IL-2 production when added to a T lymphocyte containing culture at a concentration of at least 10 μg/ml.

6. The method of Claim 1 wherein said monoclonal antibody binds to the same epitope on B7.1 as 16C10 or 7C10, or which monoclonal antibody inhibits the interaction of 16C10 or 7C10 with B7.1 and/or B7.2 antigen for inducing apoptosis of B7 antigen expressing cells.

7. The method of Claim 1, wherein the administered antibody is a primatized antibody.

8. The method of Claim 1, wherein the administered antibody is a human, chimeric mouse/human, or humanized antibody.

9. The method of Claim 1, wherein said B7.1 is human B7.1.

10. The method of Claim 1, wherein said B7.2 is human B7.2.

11. A method of treating a disease wherein the apoptosis of B cells is therapeutically beneficial comprising administering an amount of an antibody to B7.1 (CD80) and/or B7.2 (CD86) antigen sufficient to induce apoptosis of B cells.

12. The method of Claim 11, wherein said antibody is a primatized, humanized, or human monoclonal antibody.

13. The method of Claim 11, wherein said disease is a B cell cancer or lymphoma or a cancer wherein B cells promote the growth and/or metastasis of tumors.

14. The method of Claim 12, wherein said cancer is a B cell lymphoma or a B cell leukemia.

15. The method of Claim 11 wherein said disease is an autoimmune disorder or graft-vs-host disease.

16. The method of Claim 15, wherein said autoimmune disease is selected from the group consisting of idiopathic thrombocytopenia purpura, systemic lupus erythematosus, type 1 diabetes mellitus, rheumatoid arthritis, psoriasis, aplastic anemia, inflammatory bile disease, allergy and multiple sclerosis.

17. The method of Claim 12, wherein said disease is an autoimmune disorder selected from the group consisting of idiopathic thrombocytopenia purpura, systemic lupus erythematosus, type 1 diabetes mellitus, rheumatoid arthritis, psoriasis, aplastic anemia, inflammatory bile disease, allergy and multiple sclerosis, or is graft-vs-host disease.

18. The method of Claim 15, wherein said disease is graft-versus-host disease.

19. The method of Claim 12, wherein said disease is graft-versus-host disease.

20. A method of inducing apoptosis of B7 antigen expressing cells that results in synergistic induction of apoptosis comprising the combined administration of an antibody to B7 antigen and another agent that promotes apoptosis.

21. The method of Claim 20 wherein the other agent is selected from the group consisting of a chemotherapeutic, a radioconjugate, a radioimmunoconjugate, an antisense oligonucleotide, and a ribozyme.

22. The method of Claim 20 which is used to treat a B cell lymphoma or leukemia.

23. The method of Claim 20 which is used to treat a solid tumor or cancer wherein B cells promote tumor growth and/or metastasis.

24. The method of Claim 1, which further comprises the administration of recombinant protein or small molecule therapeutics.

25. The method of Claim 24, wherein the B7 antibody that promotes apoptosis is administered in combination with other recombinant protein or small molecule immunosuppressants.

26. The method of Claim 1 wherein the administered antibody does not block IL2 production in cultures comprising anti-CD3 antibody/B7Ig co-stimulated T-cells.

27. The method of Claim 1, which does not inhibit growth and/or differentiation of anti-CD3 antibody/B7Ig co-stimulated T-cells.

28. The method of Claim 1, wherein the administered antibody only partially blocks IL-10 production in a culture comprising anti-CD3 antibody/B7Ig co-stimulated T-cells.

pMS PHAGE DISPLAY VECTOR. PRO = LAC Z PROMOTOR.
L1 = OMP A LEADER. L2 = PEL B LEADER.
LIGHT = LIGHT CHAIN. HEAVY = HEAVY CHAIN.

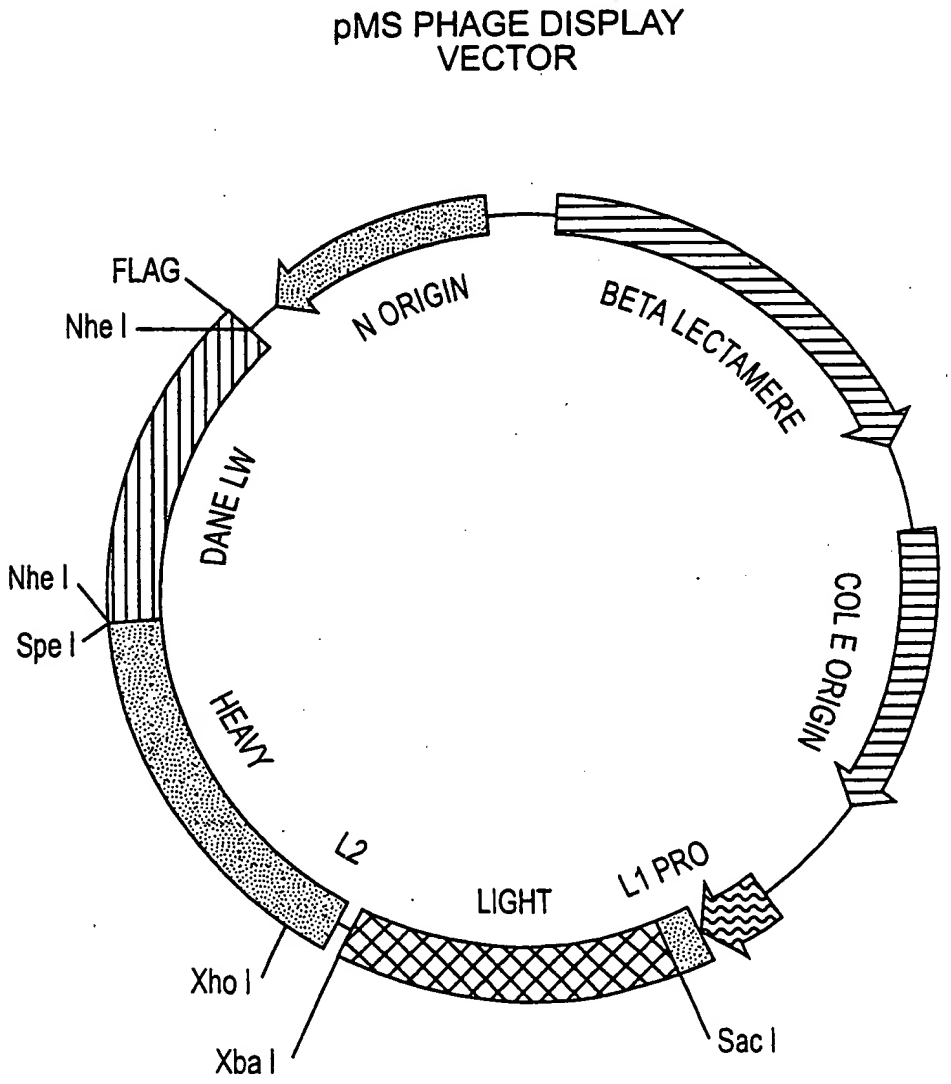
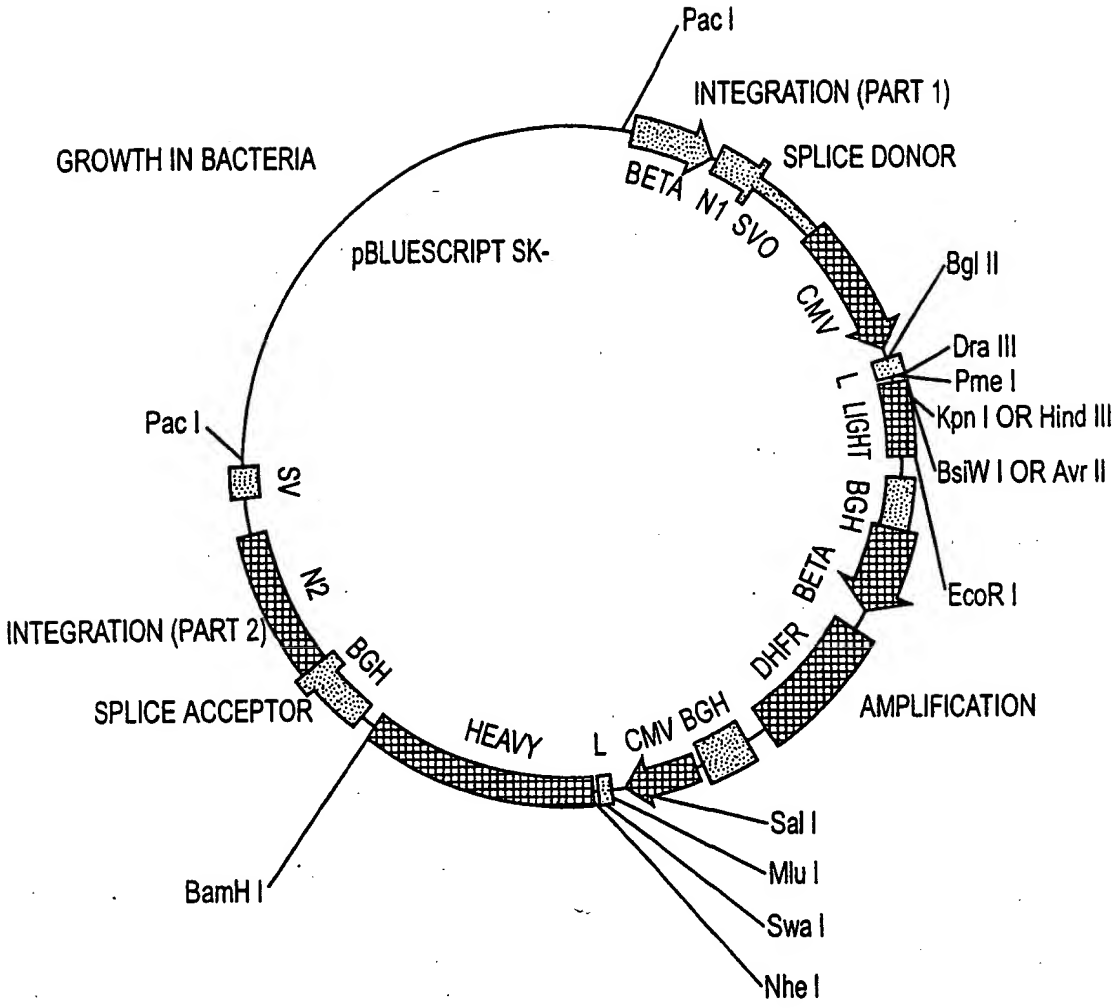



FIG. 1

NEOSPLA




CMV = CYTOMEGALOVIRUS PROMOTER/ENHANCER
BETA = MOUSE BETA GLOBIN MAJOR PROMOTER
SVO = SV40 ORIGIN
BGH = BOVINE GROWTH HORMONE POLYADENYLATION
SV = SV40 POLYADENYLATION
N1 = NEOMYCIN PHOSPHOTRANSFERASE EXON 1
N2 = NEOMYCIN PHOSPHOTRANSFERASE EXON 2
LIGHT = HUMAN IMMUNONOGLOBULIN KAPPA OR LAMBDA CONSTANT REGION
DHFR = DIHYDROFOLATE REDUCTASE
HEAVY = HUMAN IMMUNONOGLOBULIN GAMMA 1 OR GAMMA 4 PE CONSTANT REGION
L = LEADER

*FIG. 2*

LENGTH OF 7C10 LIGHT/PRIMATIZED: 705 BP; LISTED FROM: 1 TO: 705;
TRANSLATED FROM: 1 TO: 703 (ENTIRE REGION);
GENETIC CODE USED: UNIVERSAL

```
FRAME 1  M   R   V   P   A   Q   L   L   G   L   L   L   L   W   L   P   G   A   R
         ATG AGG GTC CCC GCT CAG CTC CTG GGG CTC CTG CTG CTC TGG CTC CCA GGT GCA CGA
                    9           18          27          36          45          54

         C   A   Y   E   L   T   Q   P   P   S   V   S   V   S   P   G   Q   T   A   R   I
         TGT GCC TAT GAA CTG ACT CAG CCA CCC TCG GTG TCA GTG TCC CCA GGA CAG ACG GCC AGG ATC
              63          72          81          90          99          108         117

         T   C   G   G   D   N   S   R   N   E   Y   V   H   W   Y   Q   Q   K   P   A   R
         ACC TGT GGG GGA GAC AAC AGT AGA AAT GAA TAT GTC CAC TGG TAC CAG CAG AAG CCA GCG CGG
             126         135         144         153         162         171         180

         A   P   I   L   V   I   Y   D   D   S   D   R   P   S   G   I   P   E   R   F   S
         GCC CCT ATA CTG GTC ATC TAT GAT GAT AGT GAC CGG CCC TCA GGG ATC CCT GAG CGA TTC TCT
             189         198         207         216         225         234         243

         G   S   K   S   G   N   T   A   T   L   T   I   N   G   V   E   A   G   D   E   A
         GGC TCC AAA TCA GGG AAC ACC GCC ACC CTG ACC ATC AAC GGG GTC GAG GCC GGG GAT GAG GCT
             252         261         270         279         288         297         306

         D   Y   Y   C   Q   V   W   D   R   A   S   D   H   P   V   F   G   G   G   T   R
         GAC TAT TAC TGT CAG GTG TGG GAC AGG GCT AGT GAT CAT CCG GTC TTC GGA GGA GGG ACC CGG
             315         324         333         342         351         360         369
```

FIG. 3A

```
V  T  V  L  G  Q  P  K  A  A  P  S  V  T  L  F  P  P  S  S  E
GTG ACC GTC CTA GGT CAG CCC AAG GCT GCC CCC TCG GTC ACT CTG TTC CCG CCC TCC TCT GAG
   378        387        396        405        414        423        432

E  L  Q  A  N  K  A  T  L  V  C  L  I  S  D  F  Y  P  G  A  V
GAG CTT CAA GCC AAC AAG GCC ACA CTG GTG TGT CTC ATA AGT GAC TTC TAC CCG GGA GCC GTG
   441        450        459        468        477        486        495

T  V  A  W  K  A  D  S  S  P  V  K  A  G  V  E  T  T  T  P  S
ACA GTG GCC TGG AAG GCA GAT AGC AGC CCC GTC AAG GCG GGA GTG GAG ACC ACC ACA CCC TCC
   504        513        522        531        540        549        558

K  Q  S  N  N  K  Y  A  A  S  S  Y  L  S  L  T  P  E  Q  W  K
AAA CAA AGC AAC AAC AAG TAC GCG GCC AGC AGC TAC CTG AGC CTG ACG CCT GAG CAG TGG AAG
   567        576        585        594        603        612        621

S  H  R  S  Y  S  C  Q  V  T  H  E  G  S  T  V  E  K  T  V  A
TCC CAC AGA AGC TAC AGC TGC CAG GTC ACG CAT GAA GGG AGC ACC GTG GAG AAG ACA GTG GCC
   630        639        648        657        666        675        684

P  T  E  C  S
CCT ACA GAA TGT TCA TGA
   693        702
```

FIG. 3A (CONT-1)

LENGTH OF 7C10 HEAVY/PRIMATIZED: 1431 BP; LISTED FROM: 1 TO: 1431;
TRANSLATED FROM: 1 TO: 1429 (ENTIRE REGION);
GENETIC CODE USED: UNIVERSAL

```
FRAME 1   M   K   H   L   W   F   F   L   L   L   V   A   A   P   R   W   V   L   S
          ATG AAA CAC CTG TGG TTC TTC CTC CTC CTG GTG GCA GCT CCC AGA TGG GTC CTG TCC
                    9               18              27              36              45              54

  Q   V   K   L   Q   Q   W   G   E   G   L   L   Q   P   S   E   T   L   S   R   T
  CAG GTG AAG CTG CAG CAG TGG GGC GAA GGA CTT CTG CAG CCT TCG GAG ACC CTG TCC CGC ACC
        63              72              81              90              99             108             117
  C   V   V   S   G   G   S   I   S   G   Y   Y   Y   W   T   W   I   R   Q   T   P
  TGC GTT GTC TCT GGT GGC TCC ATC AGC GGT TAC TAC TAC TGG ACC TGG ATC CGC CAG ACC CCA
        126             135             144             153             162             171             180
  G   R   G   L   E   W   I   G   H   I   Y   G   N   G   A   T   T   N   Y   N   P
  GGG AGG GGA CTG GAG TGG ATT GGC CAT ATT TAT GGT AAT GGT GCG ACC ACC AAC TAC AAT CCC
        189             198             207             216             225             234             243
  S   L   K   S   R   V   T   I   S   K   D   T   S   K   N   Q   F   F   L   N   L
  TCC CTC AAG AGT CGA GTC ACC ATT TCA AAA GAC ACG TCC AAG AAC CAG TTC TTC CTG AAC TTG
        252             261             270             279             288             297             306
  N   S   V   T   D   A   D   T   A   V   Y   Y   C   A   R   G   P   R   P   D   C
  AAT TCT GTG ACC GAC GCG GAC ACG GCC GTC TAT TAC TGT GCG AGA GGC CCT CGC CCT GAT TGC
        315             324             333             342             351             360             369
  T   T   I   C   Y   G   G   W   V   D   V   W   G   P   G   D   L   V   T   V   S
  ACA ACC ATT TGT TAT GGC GGC TGG GTC GAT GTC TGG GGC CCG GGA GAC CTG GTC ACC GTC TCC
        378             387             396             405             414             423             432
```

FIG. 3B

```
S   A   S   T   K   G   P   S   V   F   P   L   A   P   S   S   K   S   T   S   G
TCA GCT AGC ACC AAG GGC CCA TCG GTC TTC CCC CTG GCA CCC TCC TCC AAG AGC ACC TCT GGG
    441     450     459     468     477     486     495
G   T   A   A   L   G   C   L   V   K   D   Y   F   P   E   P   V   T   V   S   W
GGC ACA GCG GCC CTG GGC TGC CTG GTC AAG GAC TAC TTC CCC GAA CCG GTG ACG GTG TCG TGG
    504     513     522     531     540     549     558
N   S   G   A   L   T   S   G   V   H   T   F   P   A   V   L   Q   S   S   G   L
AAC TCA GGC GCC CTG ACC AGC GGC GTG CAC ACC TTC CCG GCT GTC CTA CAG TCC TCA GGA CTC
    567     576     585     594     603     612     621
Y   S   L   S   S   V   V   T   V   P   S   S   S   L   G   T   Q   T   Y   I   C
TAC TCC CTC AGC AGC GTG GTG ACC GTG CCC TCC AGC AGC TTG GGC ACC CAG ACC TAC ATC TGC
    630     639     648     657     666     675     684
N   V   N   H   K   P   S   N   T   K   V   D   K   K   A   E   P   K   S   C   D
AAC GTG AAT CAC AAG CCC AGC AAC ACC AAG GTG GAC AAG AAA GCA GAG CCC AAA TCT TGT GAC
    693     702     711     720     729     738     747
K   T   H   T   C   P   P   C   P   A   P   E   L   L   G   G   P   S   V   F   L
AAA ACT CAC ACA TGC CCA CCG TGC CCA GCA CCT GAA CTC CTG GGG GGA CCG TCA GTC TTC CTC
    756     765     774     783     792     801     810
F   P   P   K   P   K   D   T   L   M   I   S   R   T   P   E   V   T   C   V   V
TTC CCC CCA AAA CCC AAG GAC ACC CTC ATG ATC TCC CGG ACC CCT GAG GTC ACA TGC GTG GTG
    819     828     837     846     855     864     873
V   D   V   S   H   E   D   P   E   V   K   F   N   W   Y   V   D   G   V   E   V
GTG GAC GTG AGC CAC GAA GAC CCT GAG GTC AAG TTC AAC TGG TAC GTG GAC GGC GTG GAG GTG
    882     891     900     909     918     927     936
```

FIG. 3B (CONT-1)

```
H  N  A  K  T  K  P  R  E  E  E  Q  Y  N  S  T  Y  R  V  V  S  V
CAT AAT GCC AAG ACA AAG CCG CGG GAG GAG CAG TAC AAC AGC ACG TAC CGT GTG GTC AGC GTC
      945        954        963        972        981        990        999

L  T  V  L  H  Q  D  W  L  N  G  K  E  Y  K  C  K  V  S  N  K
CTC ACC GTC CTG CAC CAG GAC TGG CTG AAT GGC AAG GAG TAC AAG TGC AAG GTC TCC AAC AAA
     1008       1017       1026       1035       1044       1053       1062

A  L  P  A  P  I  E  K  T  I  S  K  A  K  G  Q  P  R  E  P  Q
GCC CTC CCA GCC CCC ATC GAG AAA ACC ATC TCC AAA GCC AAA GGG CAG CCC CGA GAA CCA CAG
     1071       1080       1089       1098       1107       1116       1125

V  Y  T  L  P  P  S  R  D  E  L  T  K  N  Q  V  S  L  T  C  L
GTG TAC ACC CTG CCC CCA TCC CGG GAT GAG CTG ACC AAG AAC CAG GTC AGC CTG ACC TGC CTG
     1134       1143       1152       1161       1170       1179       1188

V  K  G  F  Y  P  S  D  I  A  V  E  W  E  S  N  G  Q  P  E  N
GTC AAA GGC TTC TAT CCC AGC GAC ATC GCC GTG GAG TGG GAG AGC AAT GGG CAG CCG GAG AAC
     1197       1206       1215       1224       1233       1242       1251

N  Y  K  T  T  P  P  V  L  D  S  D  G  S  F  F  L  Y  S  K  L
AAC TAC AAG ACC ACG CCT CCC GTG CTG GAC TCC GAC GGC TCC TTC TTC CTC TAC AGC AAG CTC
     1260       1269       1278       1287       1296       1305       1314

T  V  D  K  S  R  W  Q  Q  G  N  V  F  S  C  S  V  M  H  E  A
ACC GTG GAC AAG AGC AGG TGG CAG CAG GGG AAC GTC TTC TCA TGC TCC GTG ATG CAT GAG GCT
     1323       1332       1341       1350       1359       1368       1377

L  H  N  H  Y  T  Q  K  S  L  S  L  S  P  G  K
CTG CAC AAC CAC TAC ACG CAG AAG AGC CTC TCC CTG TCT CCG GGT AAA TGA
     1386       1395       1404       1413       1422       1431
```

FIG. 3B (CONT-2)

LENGTH OF 7B6 LIGHT/PRIMATIZED: 720bp; LISTED FROM : 1 TO: 720;
TRANSLATED FROM: 1 TO: 718 (ENTIRE REGION);
GENETIC CODE USED: UNIVERSAL

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FRAME 1 | | M | S | L | P | A | Q | L | L | G | L | L | L | L | C | V | P | G | S | S |
| | | ATG | AGC | CTC | CCT | GCT | CAG | CTC | CTC | GGG | CTG | CTA | TTG | CTC | TGC | GTC | CCC | GGG | TCC | AGT |
| | | | | 9 | | | 18 | | | 27 | | | 36 | | | 45 | | | 54 | |
| G | E | V | V | M | T | Q | S | P | L | S | L | P | I | T | P | G | E | P | A | S |
| GGG | GAA | GTT | GTG | ATG | ACT | CAG | TCT | CCA | CTG | TCC | CTT | CCC | ATC | ACA | CCT | GGA | GAG | CCG | GCC | TCC |
| | 63 | | | 72 | | | 81 | | | 90 | | | 99 | | | 108 | | | 117 | |
| I | S | C | R | S | S | Q | S | L | K | H | S | N | G | D | T | F | L | S | W | Y |
| ATC | TCC | TGT | AGG | TCT | AGT | CAA | AGC | CTT | AAA | CAC | AGT | AAT | GGA | GAC | ACC | TTC | CTG | AGT | TGG | TAT |
| | 126 | | | 135 | | | 144 | | | 153 | | | 162 | | | 171 | | | 180 | |
| Q | Q | K | P | G | Q | P | P | R | L | L | I | Y | K | V | S | N | R | D | S | G |
| CAG | CAG | AAG | CCA | GGC | CAA | CCT | CCA | AGG | CTC | CTG | ATT | TAT | AAG | GTT | TCT | AAC | CGG | GAC | TCT | GGG |
| | 189 | | | 198 | | | 207 | | | 216 | | | 225 | | | 234 | | | 243 | |
| V | P | D | R | F | S | G | S | G | A | G | T | D | F | T | L | K | I | S | A | V |
| GTC | CCA | GAC | AGA | TTC | AGC | GGC | AGT | GGG | GCA | GGG | ACA | GAT | TTC | ACA | CTG | AAA | ATC | AGC | GCA | GTG |
| | 252 | | | 261 | | | 270 | | | 279 | | | 288 | | | 297 | | | 306 | |
| E | A | E | D | V | G | V | Y | F | C | G | Q | G | T | R | T | P | P | T | F | G |
| GAG | GCT | GAA | GAT | GTT | GGG | GTT | TAT | TTC | TGC | GGG | CAA | GGT | ACA | AGG | ACT | CCT | CCC | ACT | TTC | GGC |
| | 315 | | | 324 | | | 333 | | | 342 | | | 351 | | | 360 | | | 369 | |
| G | G | T | K | V | E | I | K | R | T | V | A | A | P | S | V | F | I | F | P | P |
| GGA | GGG | ACC | AAG | GTG | GAA | ATC | AAA | CGT | ACG | GTG | GCT | GCA | CCA | TCT | GTC | TTC | ATC | TTC | CCG | CCA |
| | 378 | | | 387 | | | 396 | | | 405 | | | 414 | | | 423 | | | 432 | |

FIG. 4A

```
S   D   E   Q   L   K   S   G   T   A   S   V   V   C   L   L   N   N   F   Y   P
TCT GAT GAG CAG TTG AAA TCT GGA ACT GCC TCT GTT GTG TGC CTG CTG AAT AAC TTC TAT CCC
    441             450             459             468             477
    486             495
R   E   A   K   V   Q   W   K   V   D   N   A   L   Q   S   G   N   S   Q   E   S
AGA GAG GCC AAA GTA CAG TGG AAG GTG GAT AAC GCC CTC CAA TCG GGT AAC TCC CAG GAG AGT
    504             513             522             531             540
    549             558
V   T   E   Q   D   S   K   D   S   T   Y   S   L   S   S   T   L   T   L   S   K
GTC ACA GAG CAG GAC AGC AAG GAC AGC ACC TAC AGC CTC AGC AGC ACC CTG ACG CTG AGC AAA
    567             576             585             594             603
    612             621
A   D   Y   E   K   H   K   V   Y   A   C   E   V   T   H   Q   G   L   S   S   P
GCA GAC TAC GAG AAA CAC AAA GTC TAC GCC TGC GAA GTC ACC CAT CAG GGC CTG AGC TCG CCC
    630             639             648             657             666
    675             684
V   T   K   S   F   N   R   G   E   C
GTC ACA AAG AGC TTC AAC AGG GGA GAG TGT TGA
    693             702             711
    720
```

FIG. 4A (CONT-1)

LENGTH OF 7B6 HEAVY/PRIMATIZED: 1437bp; LISTED FROM : 1 TO: 1437;
TRANSLATED FROM: 1 TO: 1435 (ENTIRE REGION);
GENETIC CODE USED: UNIVERSAL

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FRAME 1 | | M | G | W | S | L | I | L | L | F | L | V | A | V | A | T | R | V | Q | C |
| | | ATG | GGT | TGG | AGC | CTC | ATC | TTG | CTC | TTC | CTT | GTC | GCT | GTT | GCT | ACG | CGT | GTC | CAG | TGT |
| | | | | 9 | | | 18 | | | 27 | | | 36 | | | 45 | | | 54 | |
| E | V | Q | L | V | E | S | G | G | G | L | V | Q | P | G | G | S | L | R | V | S |
| GAG | GTG | CAA | CTG | GTG | GAG | TCT | GGG | GGA | GGC | TTG | GTC | CAG | CCT | GGC | GGG | TCC | CTG | AGA | GTC | TCC |
| | 63 | | | 72 | | | 81 | | | 90 | | | 99 | | | 108 | | | 117 | |
| C | A | V | S | G | F | T | F | S | D | H | Y | M | Y | W | F | R | Q | A | P | G |
| TGT | GCA | GTC | TCT | GGA | TTC | ACC | TTC | AGT | GAC | CAC | TAC | ATG | TAT | TGG | TTC | CGC | CAG | GCT | CCA | GGG |
| | 126 | | | 135 | | | 144 | | | 153 | | | 162 | | | 171 | | | 180 | |
| K | G | P | E | W | V | G | F | I | R | N | K | P | N | G | G | T | T | E | Y | A |
| AAG | GGG | CCG | GAA | TGG | GTA | GGT | TTC | ATT | AGA | AAC | AAA | CCG | AAC | GGT | GGG | ACA | ACA | GAA | TAC | GCC |
| | 189 | | | 198 | | | 207 | | | 216 | | | 225 | | | 234 | | | 243 | |
| A | S | V | K | D | R | F | T | I | S | R | D | D | S | K | S | I | A | Y | L | Q |
| GCG | TCT | GTG | AAA | GAC | AGA | TTC | ACC | ATC | TCC | AGA | GAT | GAT | TCC | AAA | AGC | ATC | GCC | TAT | CTG | CAA |
| | 252 | | | 261 | | | 270 | | | 279 | | | 288 | | | 297 | | | 306 | |
| M | S | S | L | K | I | E | D | T | A | V | Y | Y | C | T | T | S | Y | I | S | H |
| ATG | AGC | AGC | CTG | AAA | ATC | GAG | GAC | ACG | GCC | GTC | TAT | TAC | TGT | ACT | ACA | TCC | TAC | ATT | TCA | CAT |
| | 315 | | | 324 | | | 333 | | | 342 | | | 351 | | | 360 | | | 369 | |
| C | R | G | G | V | C | Y | G | G | Y | F | E | F | W | G | Q | G | A | L | V | T |
| TGT | CGG | GGT | GGT | GTC | TGC | TAT | GGA | GGT | TAC | TTC | GAA | TTC | TGG | GGC | CAG | GGC | GCC | CTG | GTC | ACC |
| | 378 | | | 387 | | | 396 | | | 405 | | | 414 | | | 423 | | | 432 | |

FIG. 4B

```
V   S   S   A   S   T   K   G   P   S   V   F   P   L   A   P   S   S   S   K   S   T
GTC TCC TCA GCT AGC ACC AAG GGC CCA TCG GTC TTC CCC CTG GCA CCC TCC TCC TCC AAG AGC ACC
    441         450         459         468         477         486         495

S   G   G   T   A   A   L   G   C   L   V   K   D   Y   F   P   E   P   V   T   V
TCT GGG GGC ACA GCG GCC CTG GGC TGC CTG GTC AAG GAC TAC TTC CCC GAA CCG GTG ACG GTG
    504         513         522         531         540         549         558

S   W   N   S   G   A   L   T   S   G   V   H   T   F   P   A   V   L   Q   S   S
TCG TGG AAC TCA GGC GCC CTG ACC AGC GGC GTG CAC ACC TTC CCG GCT GTC CTA CAG TCC TCA
    567         576         585         594         603         612         621

G   L   Y   S   L   S   S   V   V   T   V   P   S   S   S   S   L   G   T   Q   T   Y
GGA CTC TAC TCC CTC AGC AGC GTG GTG ACC GTG CCC TCC AGC AGC TTG GGC ACC CAG ACC TAC
    630         639         648         657         666         675         684

I   C   N   V   N   H   K   P   S   N   T   K   V   D   K   K   A   E   P   K   S
ATC TGC AAC GTG AAT CAC AAG CCC AGC AAC ACC AAG GTG GAC AAG AAA GCA GAG CCC AAA TCT
    693         702         711         720         729         738         747

C   D   K   T   H   T   C   P   P   C   P   A   P   E   L   L   G   G   P   S   V
TGT GAC AAA ACT CAC ACA TGC CCA CCG TGC CCA GCA CCT GAA CTC CTG GGG GGA CCG TCA GTC
    756         765         774         783         792         801         810

F   L   F   P   P   K   P   K   D   T   L   M   I   S   R   T   P   E   V   T   C
TTC CTC TTC CCC CCA AAA CCC AAG GAC ACC CTC ATG ATC TCC CGG ACC CCT GAG GTC ACA TGC
    819         828         837         846         855         864         873

V   V   V   D   V   S   H   E   D   P   E   V   K   F   N   W   Y   V   D   G   V
GTG GTG GTG GAC GTG AGC CAC GAA GAC CCT GAG GTC AAG TTC AAC TGG TAC GTG GAC GGC GTG
    882         891         900         909         918         927         936
```

FIG. 4B (CONT-1)

```
E  V  H  N  A  K  T  K  P  R  E  E  Q  Y  N  S  T  Y  R  V  V
GAG GTG CAT AAT GCC AAG ACA AAG CCG CGG GAG GAG CAG TAC AAC AGC ACG TAC CGT GTG GTC
   945        954        963        972        981        990        999
S  V  L  T  V  L  H  Q  D  W  L  N  G  K  E  Y  K  C  K  V  S
AGC GTC CTC ACC GTC CTG CAC CAG GAC TGG CTG AAT GGC AAG GAG TAC AAG TGC AAG GTC TCC
   1008       1017       1026       1035       1044       1053       1062
N  K  A  L  P  A  P  I  E  K  T  I  S  K  A  K  G  Q  P  R  E
AAC AAA GCC CTC CCA GCC CCC ATC GAG AAA ACC ATC TCC AAA GCC AAA GGG CAG CCC CGA GAA
   1071       1080       1089       1098       1107       1116       1125
P  Q  V  Y  T  L  P  P  S  R  D  E  L  T  K  N  Q  V  S  L  T
CCA CAG GTG TAC ACC CTG CCC CCA TCC CGG GAT GAG CTG ACC AAG AAC CAG GTC AGC CTG ACC
   1134       1143       1152       1161       1170       1179       1188
C  L  V  K  G  F  Y  P  S  D  I  A  V  E  W  E  S  N  G  Q  P
TGC CTG GTC AAA GGC TTC TAT CCC AGC GAC ATC GCC GTG GAG TGG GAG AGC AAT GGG CAG CCG
   1197       1206       1215       1224       1233       1242       1251
E  N  N  Y  K  T  T  P  P  V  L  D  S  D  G  S  F  F  L  Y  S
GAG AAC AAC TAC AAG ACC ACG CCT CCC GTG CTG GAC TCC GAC GGC TCC TTC TTC CTC TAC AGC
   1260       1269       1278       1287       1296       1305       1314
K  L  T  V  D  K  S  R  W  Q  Q  G  N  V  F  S  C  S  V  M  H
AAG CTC ACC GTG GAC AAG AGC AGG TGG CAG CAG GGG AAC GTC TTC TCA TGC TCC GTG ATG CAT
   1323       1332       1341       1350       1359       1368       1377
E  A  L  H  N  H  Y  T  Q  K  S  L  S  L  S  P  G  K
GAG GCT CTG CAC AAC CAC TAC ACG CAG AAG AGC CTC TCC CTG TCT CCG GGT AAA TGA
   1386       1395       1404       1413       1422       1431
```

FIG. 4B (CONT-2)

LENGTH OF 16C10 LAMBDA/PRIMATIZED : 711 bp; LISTED FROM: 1 TO: 711;
TRANSLATED FROM: 1 TO: 709 (ENTIRE REGION);
GENETIC CODE USED: UNIVERSAL

```
FRAME 1 M   R   V   P   A   Q   L   L   G   L   L   L   L   W   L   P   G   A   R
        ATG AGG GTC CCC GCT CAG CTC CTG GGG CTC CTG CTG CTC TGG CTC CCA GGT GCA CGA
                  9           18          27          36          45          54
C   E   S   V   L   T   Q   P   P   S   V   S   G   A   P   G   Q   K   V   T   I
TGT GAG TCT GTC CTG ACA CAG CCG CCC TCA GTG TCT GGG GCC CCA GGG CAG AAG GTC ACC ATC
      63          72          81          90          99          108         117
S   C   T   G   S   T   S   N   I   G   G   Y   D   L   H   W   Y   Q   Q   L   P
TCG TGC ACT GGG AGC ACC TCC AAC ATT GGA GGT TAT GAT CTA CAT TGG TAC CAG CAG CTC CCA
      126         135         144         153         162         171         180
G   T   A   P   K   L   L   I   Y   D   I   N   K   R   P   S   G   I   S   D   R
GGA ACG GCC CCC AAA CTC CTC ATC TAT GAC ATT AAC AAG CGA CCC TCA GGA ATT TCT GAC CGA
      189         198         207         216         225         234         243
F   S   G   S   K   S   G   T   A   A   S   L   A   I   T   G   L   Q   T   E   D
TTC TCT GGC TCC AAG TCT GGT ACC GCG GCC TCC CTG GCC ATC ACT GGG CTC CAG ACT GAG GAT
      252         261         270         279         288         297         306
E   A   D   Y   Y   C   Q   S   Y   D   S   S   L   N   A   Q   V   F   G   G   G
GAG GCT GAT TAT TAC TGC CAG TCC TAT GAC AGC AGC CTG AAT GCT CAG GTA TTC GGA GGA GGG
      315         324         333         342         351         360         369
```

FIG. 5A

```
T   R   L   T   V   L   G   Q   P   K   A   A   P   S   V   T   L   F   P   P   S
ACC CGG CTG ACC GTC CTA GGT CAG CCC AAG GCT GCC CCC TCG GTC ACT CTG TTC CCG CCC TCC
    378         387         396         405         414         423         432
S   E   E   L   Q   A   N   K   A   T   L   V   C   L   I   S   D   F   Y   P   G
TCT GAG GAG CTT CAA GCC AAC AAG GCC ACA CTG GTG TGT CTC ATA AGT GAC TTC TAC CCG GGA
    441         450         459         468         477         486         495
A   V   T   V   A   W   K   A   D   S   S   P   V   K   A   G   V   E   T   T   T
GCC GTG ACA GTG GCC TGG AAG GCA GAT AGC AGC CCC GTC AAG GCG GGA GTG GAG ACC ACC ACA
    504         513         522         531         540         549         558
P   S   K   Q   S   N   N   K   Y   A   A   S   S   Y   L   S   L   T   P   E   Q
CCC TCC AAA CAA AGC AAC AAC AAG TAC GCG GCC AGC AGC TAC CTG AGC CTG ACG CCT GAG CAG
    567         576         585         594         603         612         621
W   K   S   H   R   S   Y   S   C   Q   V   T   H   E   G   S   T   V   E   K   T
TGG AAG TCC CAC AGA AGC TAC AGC TGC CAG GTC ACG CAT GAA GGG AGC ACC GTG GAG AAG ACA
    630         639         648         657         666         675         684
V   A   P   T   E   C   S
GTG GCC CCT ACA GAA TGT TCA TGA
    693         702         711
```

FIG. 5A (CONT-1)

LENGTH OF 16C10 HEAVY/PRIMATIZED: 1431 BP; LISTED FROM: 1 TO: 1431;
TRANSLATED FROM: 1 TO: 1429 (ENTIRE REGION);
GENETIC CODE USED: UNIVERSAL

```
FRAME 1  M   K   H   L   W   F   F   L   L   L   V   A   A   P   R   W   V   L   S
         ATG AAA CAC CTG TGG TTC TTC CTC CTC CTG GTG GCA GCT CCC AGA TGG GTC CTG TCC
                   9                  18                  27                  36                  45                  54

         Q   V   Q   L   Q   E   S   G   P   G   L   V   K   P   S   E   T   L   S   L   T
         CAG GTG CAG CTG CAG GAG TCG GGC CCA GGA CTG GTG AAG CCT TCG GAG ACC CTG TCC CTC ACC
               63                  72                  81                  90                  99                  108                 117

         C   A   V   S   G   G   S   I   S   G   G   Y   G   W   G   W   I   R   Q   P   P
         TGC GCT GTC TCT GGT GGC TCC ATC AGC GGT GGT TAT GGC TGG GGC TGG ATC CGC CAG CCC CCA
               126                 135                 144                 153                 162                 171                 180

         G   K   G   L   E   W   I   G   S   F   Y   S   S   S   G   N   T   Y   Y   N   P
         GGG AAG GGG CTG GAG TGG ATT GGG AGT TTC TAT AGT AGT AGT GGG AAC ACC TAC TAC AAC CCC
               189                 198                 207                 216                 225                 234                 243

         S   L   K   S   Q   V   T   I   S   T   D   T   S   K   N   Q   F   S   L   K   L
         TCC CTC AAG AGT CAA GTC ACC ATT TCA ACA GAC ACG TCC AAG AAC CAG TTC TCC CTG AAG CTG
               252                 261                 270                 279                 288                 297                 306

         N   S   M   T   A   A   D   T   A   V   Y   Y   C   V   R   D   R   L   F   S   V
         AAC TCT ATG ACC GCC GCG GAC ACG GCC GTG TAT TAC TGT GTG AGA GAT CGT CTT TTT TCA GTT
               315                 324                 333                 342                 351                 360                 369

         V   G   M   V   Y   N   N   W   F   D   V   W   G   P   G   V   L   V   T   V   S
         GTT GGA ATG GTT TAC AAC AAC TGG TTC GAT GTC TGG GGC CCG GGA GTC CTG GTC ACC GTC TCC
               378                 387                 396                 405                 414                 423                 432
```

FIG. 5B

```
S   A   S   T   K   G   P   S   V   F   P   L   A   P   S   S   K   S   T   S   G
TCA GCT AGC ACC AAG GGC CCA TCG GTC TTC CCC CTG GCA CCC TCC TCC AAG AGC ACC TCT GGG
    441         450         459         468         477         486         495
G   T   A   A   L   G   C   L   V   K   D   Y   F   P   E   P   V   T   V   S   W
GGC ACA GCG GCC CTG GGC TGC CTG GTC AAG GAC TAC TTC CCC GAA CCG GTG ACG GTG TCG TGG
    504         513         522         531         540         549         558
N   S   G   A   L   T   S   G   V   H   T   F   P   A   V   L   Q   S   S   G   L
AAC TCA GGC GCC CTG ACC AGC GGC GTG CAC ACC TTC CCG GCT GTC CTA CAG TCC TCA GGA CTC
    567         576         585         594         603         612         621
Y   S   L   S   S   V   V   T   V   P   S   S   S   L   G   T   Q   T   Y   I   C
TAC TCC CTC AGC AGC GTG GTG ACC GTG CCC TCC AGC AGC TTG GGC ACC CAG ACC TAC ATC TGC
    630         639         648         657         666         675         684
N   V   N   H   K   P   S   N   T   K   V   D   K   K   A   E   P   K   S   C   D
AAC GTG AAT CAC AAG CCC AGC AAC ACC AAG GTG GAC AAG AAA GCA GAG CCC AAA TCT TGT GAC
    693         702         711         720         729         738         747
K   T   H   T   C   P   P   C   P   A   P   E   L   L   G   G   P   S   V   F   L
AAA ACT CAC ACA TGC CCA CCG TGC CCA GCA CCT GAA CTC CTG GGG GGA CCG TCA GTC TTC CTC
    756         765         774         783         792         801         810
F   P   P   K   P   K   D   T   L   M   I   S   R   T   P   E   V   T   C   V   V
TTC CCC CCA AAA CCC AAG GAC ACC CTC ATG ATC TCC CGG ACC CCT GAG GTC ACA TGC GTG GTG
    819         828         837         846         855         864         873
V   D   V   S   H   E   D   P   E   V   K   F   N   W   Y   V   D   G   V   E   V
GTG GAC GTG AGC CAC GAA GAC CCT GAG GTC AAG TTC AAC TGG TAC GTG GAC GGC GTG GAG GTG
    882         891         900         909         918         927         936
```

FIG. 5B (CONT-1)

```
H   N   A   K   T   K   P   R   E   E   Q   Y   N   S   T   Y   R   V   V   S   V
CAT AAT GCC AAG ACA AAG CCG CGG GAG GAG CAG TAC AAC AGC ACG TAC CGT GTG GTC AGC GTC
    945         954         963         972         981         990         999
L   T   V   L   H   Q   D   W   L   N   G   K   E   Y   K   C   K   V   S   N   K
CTC ACC GTC CTG CAC CAG GAC TGG CTG AAT GGC AAG GAG TAC AAG TGC AAG GTC TCC AAC AAA
   1008        1017        1026        1035        1044        1053        1062
A   L   P   A   P   I   E   K   T   I   S   K   A   K   G   Q   P   R   E   P   Q
GCC CTC CCA GCC CCC ATC GAG AAA ACC ATC TCC AAA GCC AAA GGG CAG CCC CGA GAA CCA CAG
   1071        1080        1089        1098        1107        1116        1125
V   Y   T   L   P   P   S   R   D   E   L   T   K   N   Q   V   S   L   T   C   L
GTG TAC ACC CTG CCC CCA TCC CGG GAT GAG CTG ACC AAG AAC CAG GTC AGC CTG ACC TGC CTG
   1134        1143        1152        1161        1170        1179        1188
V   K   G   F   Y   P   S   D   I   A   V   E   W   E   S   N   G   Q   P   E   N
GTC AAA GGC TTC TAT CCC AGC GAC ATC GCC GTG GAG TGG GAG AGC AAT GGG CAG CCG GAG AAC
   1197        1206        1215        1224        1233        1242        1251
N   Y   K   T   T   P   P   V   L   D   S   D   G   S   F   F   L   Y   S   K   L
AAC TAC AAG ACC ACG CCT CCC GTG CTG GAC TCC GAC GGC TCC TTC TTC CTC TAC AGC AAG CTC
   1260        1269        1278        1287        1296        1305        1314
T   V   D   K   S   R   W   Q   Q   G   N   V   F   S   C   S   V   M   H   E   A
ACC GTG GAC AAG AGC AGG TGG CAG CAG GGG AAC GTC TTC TCA TGC TCC GTG ATG CAT GAG GCT
   1323        1332        1341        1350        1359        1368        1377
L   H   N   H   Y   T   Q   K   S   L   S   L   S   P   G   K
CTG CAC AAC CAC TAC ACG CAG AAG AGC CTC TCC CTG TCT CCG GGT AAA TGA
   1386        1395        1404        1413        1422        1431
```

FIG. 5B (CONT-2)

COMPETITIVE BINDING OF CTLA-4Ig-BIOTIN TO B7-1 TRANSFECTED CHO CELLS IN PRESENCE OF P16C10 MAb CTLA-4Ig AND B7-1Ig FUSION PROTEINS

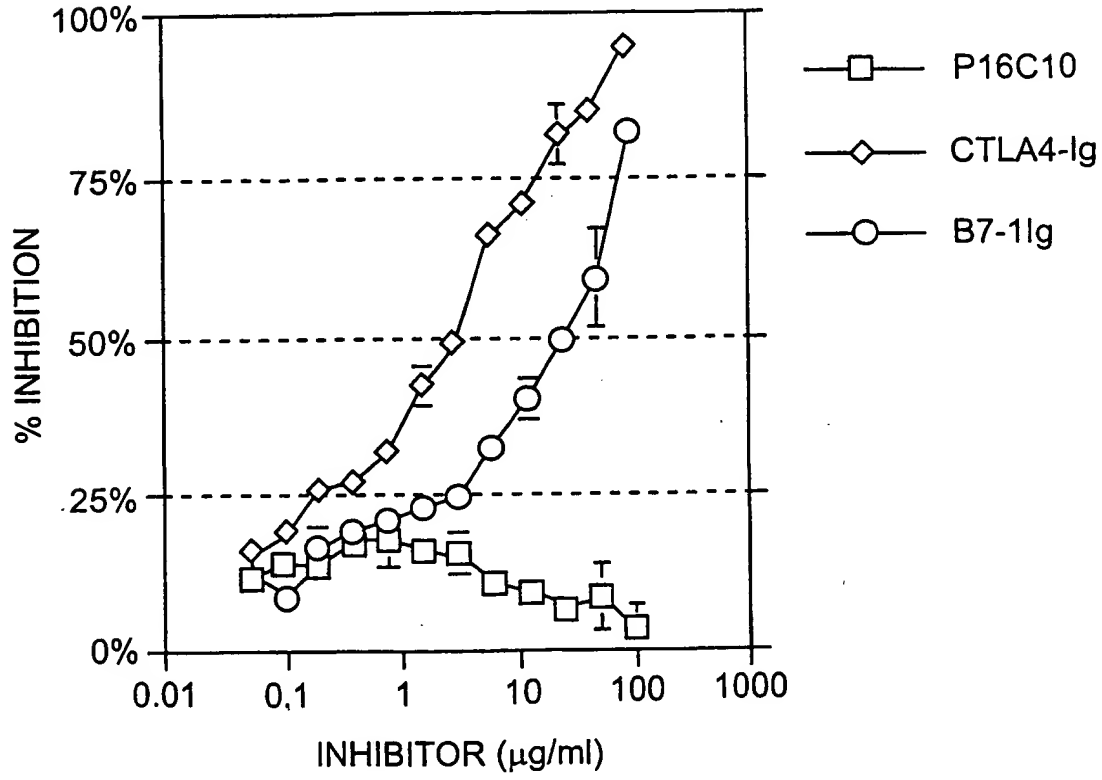



FIG. 6

COMPETITIVE BINDING OF P16C10-BIOTIN TO B7-1 TRANSFECTED CHO CELLS IN PRESENCE OF P16C10 MAb CTLA-4Ig AND B7-1Ig FUSION PROTEINS

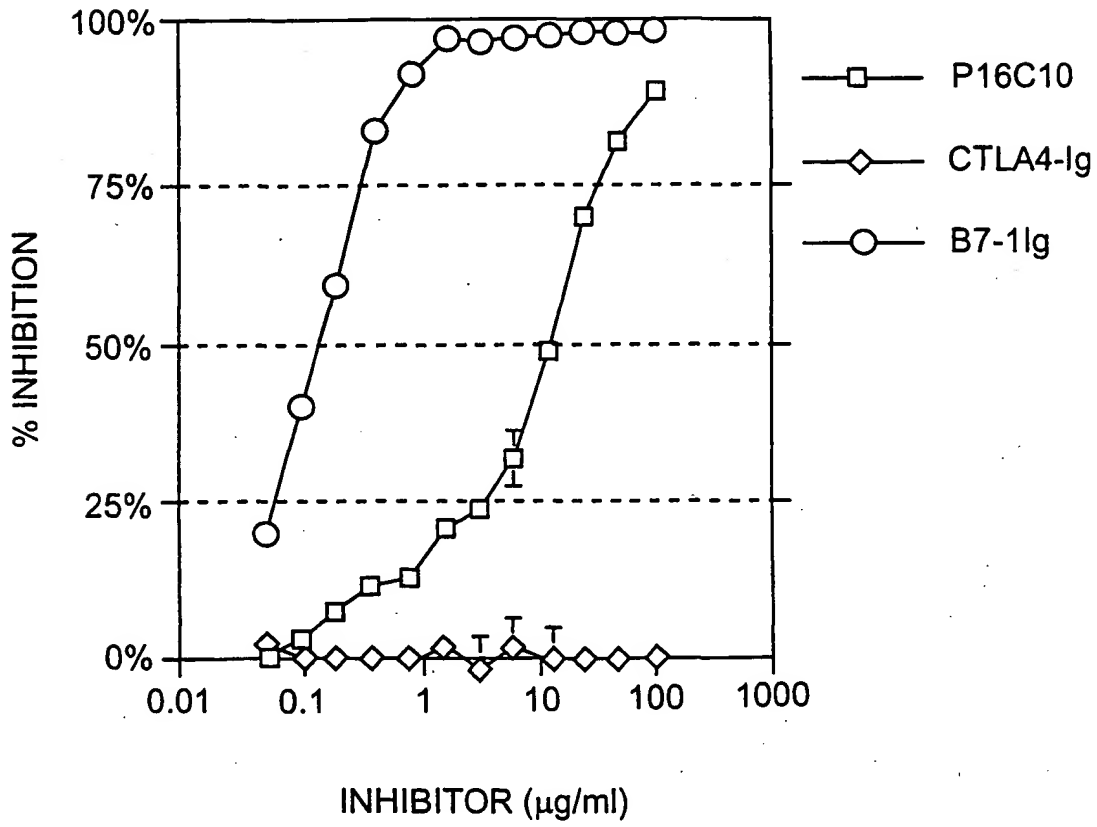



FIG. 7

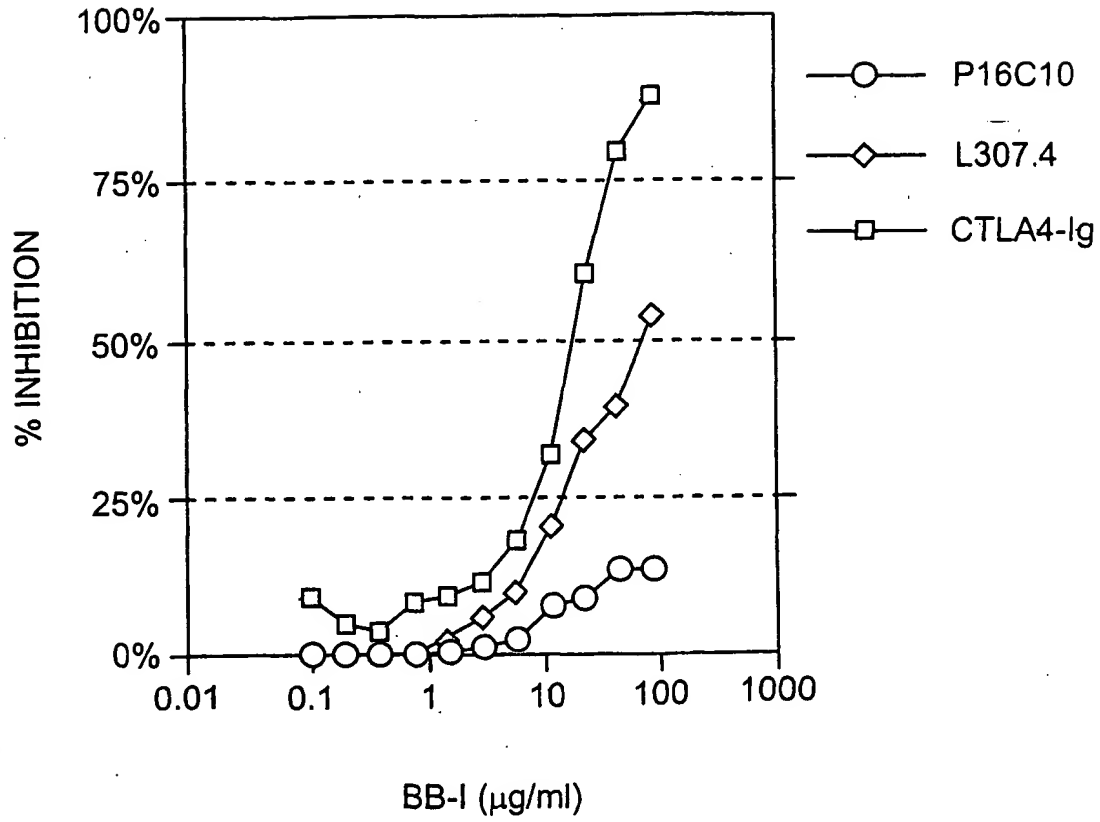



FIG. 8

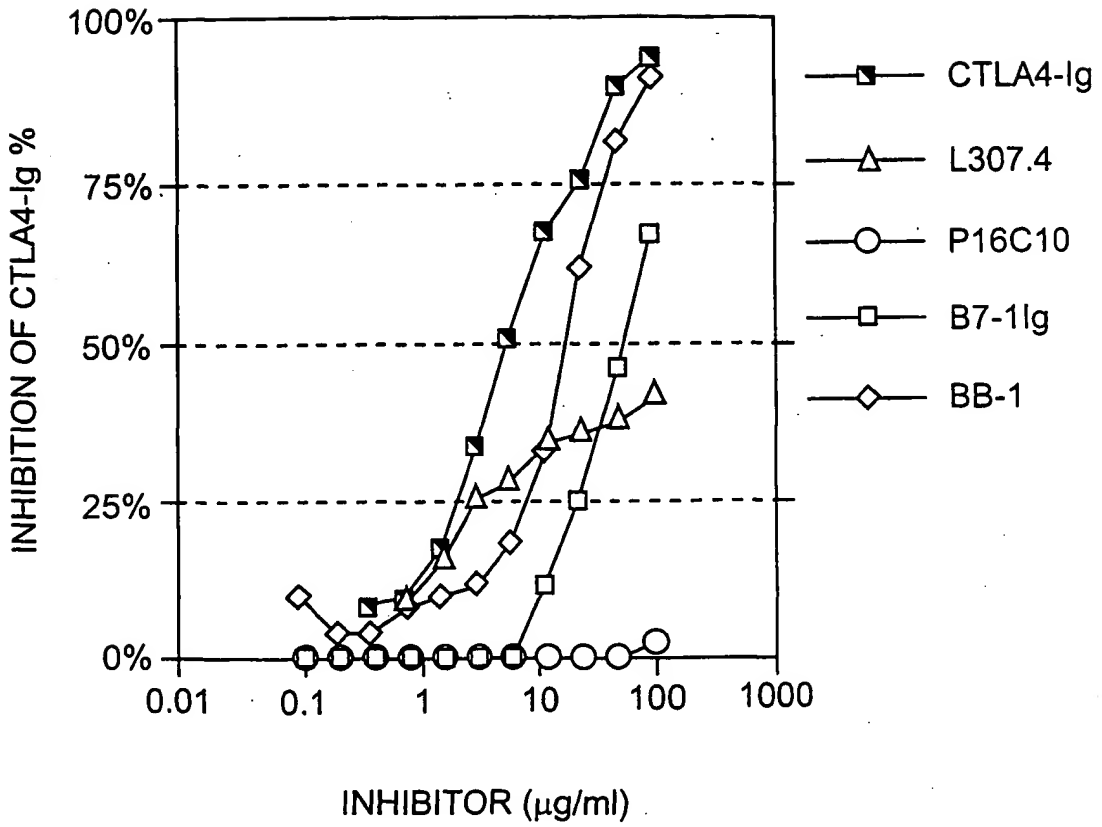



FIG. 9

COMPETITIVE INHIBITION OF RADIOLABELED B7-1IG BINDING TO CD28 RECEPTORS ON ISOLATED NON-ACTIVATED PERIPHERAL BLOOD T CELLS USING UNLABELED BINDING PROTEINS RECOGNIZING EITHER B7-1 OR CD28

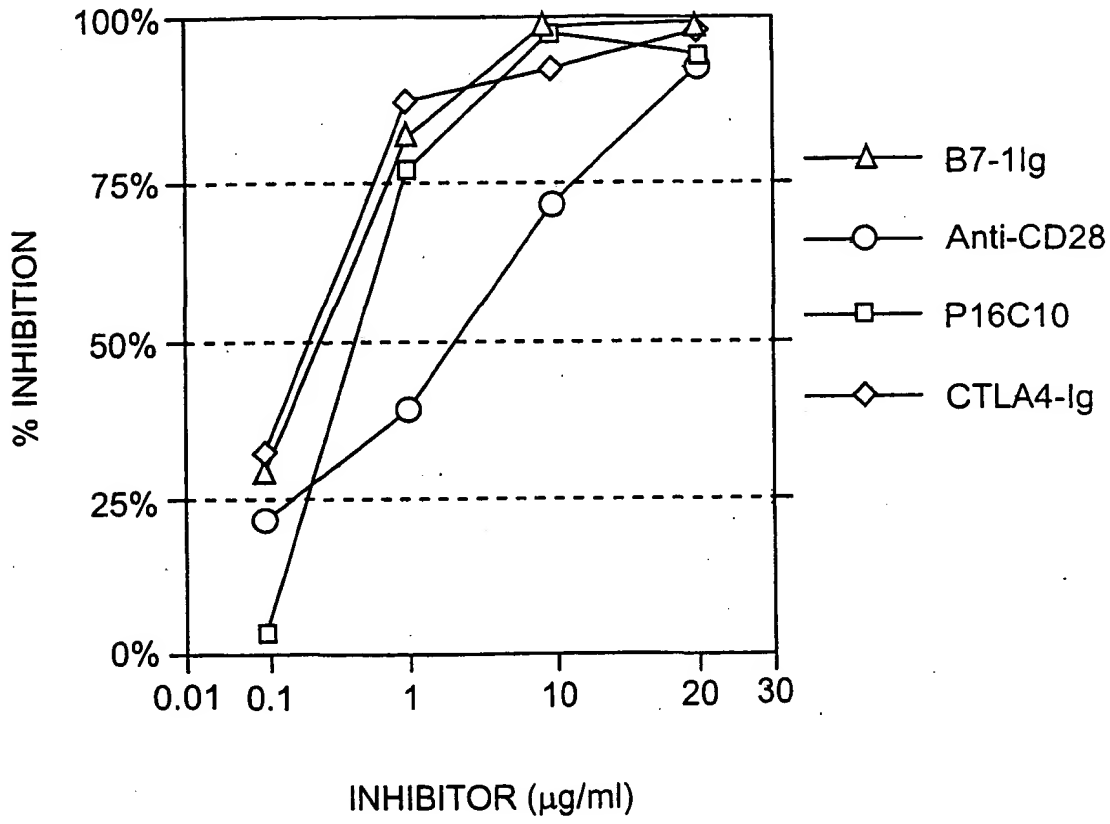



FIG. 10

IDEC-114 DOES NOT BLOCK IL-2 PRODUCTION INDUCED BY CO-STIMULATION WITH ANTI-CD3 AND B7Ig COATED LATEX MICROSPHERES

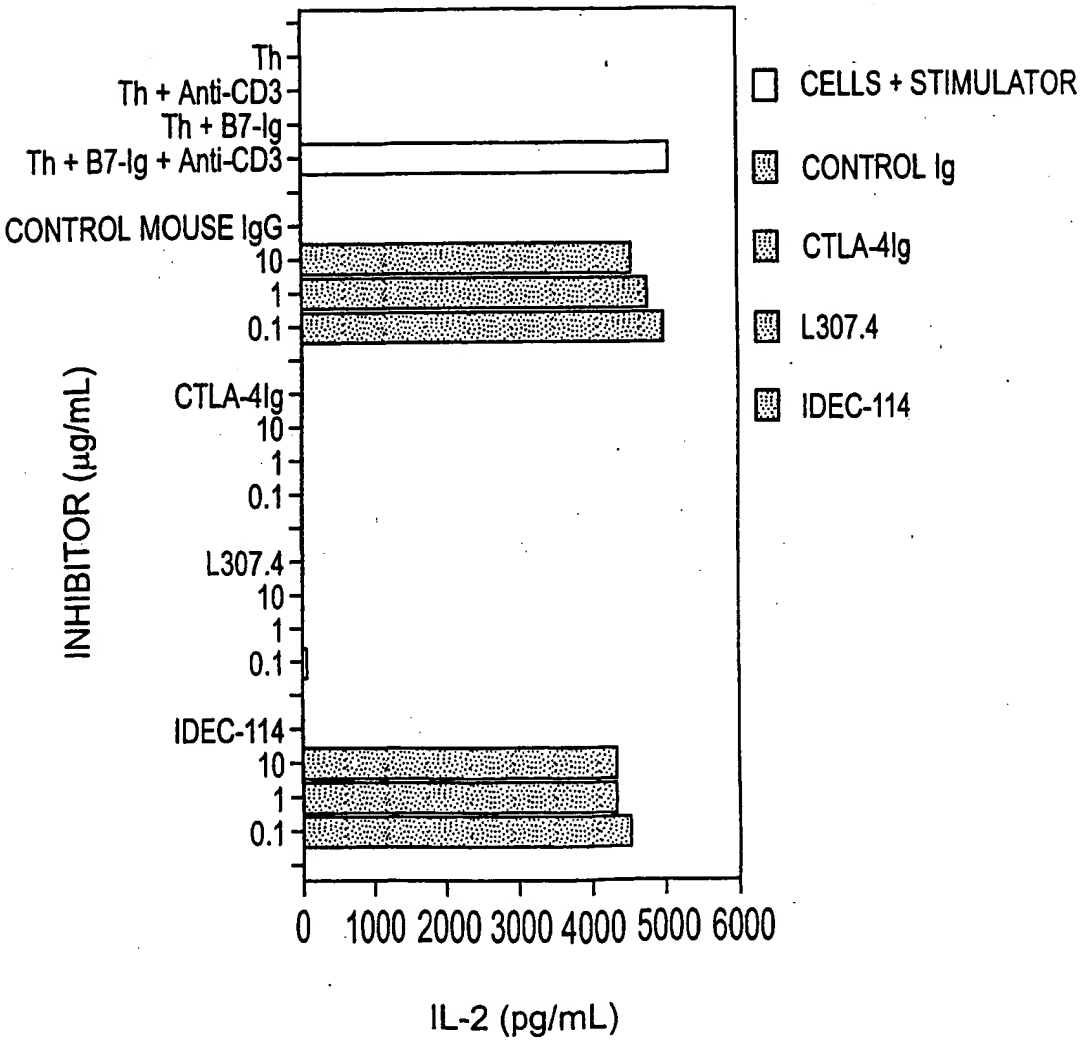



FIG. 11

IDEC-114 DOES NOT BLOCK T CELL GROWTH WHEN CO-STIMULATED BY Anti-CD3 AND B7Ig COATED LATEX MICROSPHERES

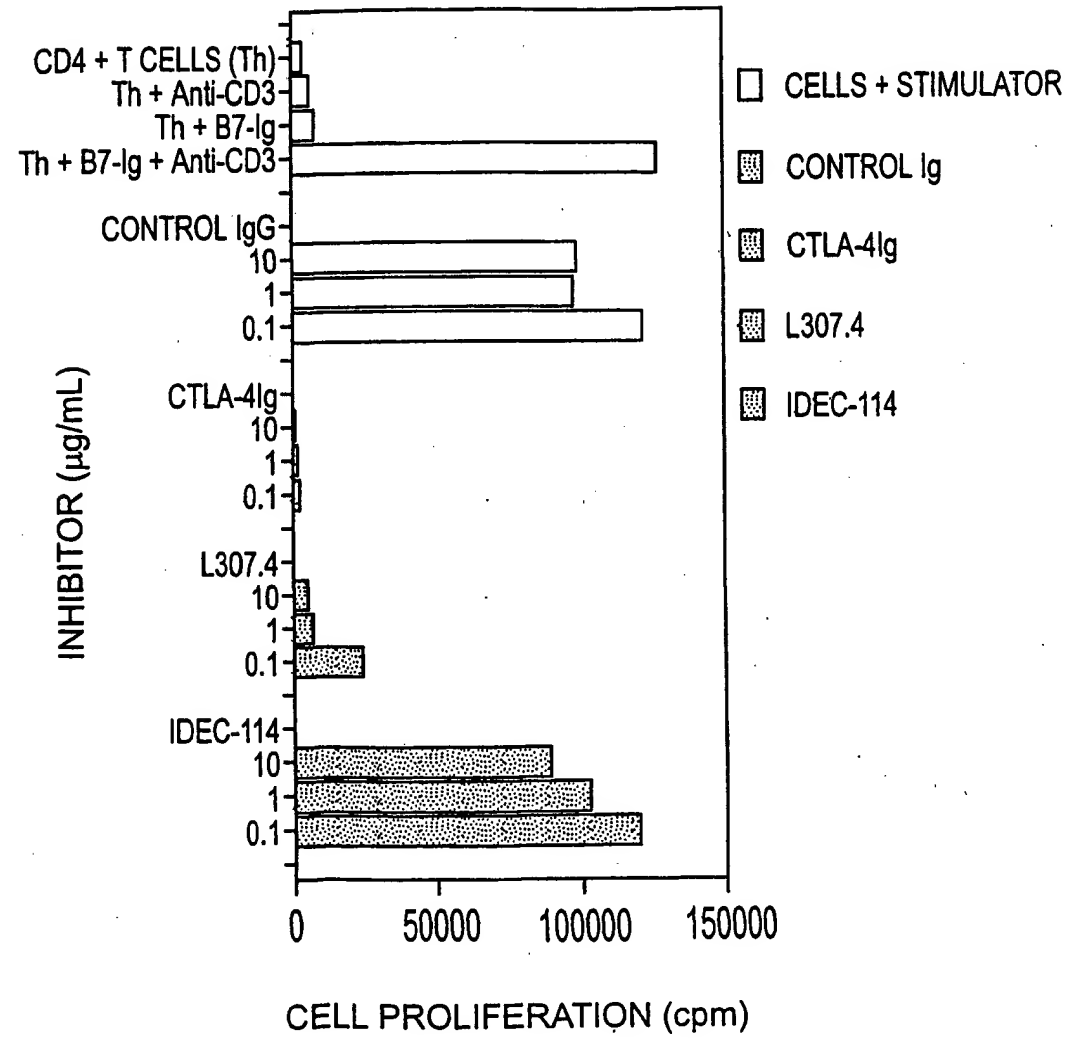



FIG. 12

PRODUCTION OF IL-10 BY CO-STIMULATION WITH ANTI-CD3:B7-Ig (1:10) LATEX MICROSPHERES IS INHIBITED BY CTLA-4Ig, AND ANTI-CD80 ANTIBODIES L307.4 AND IDEC-114

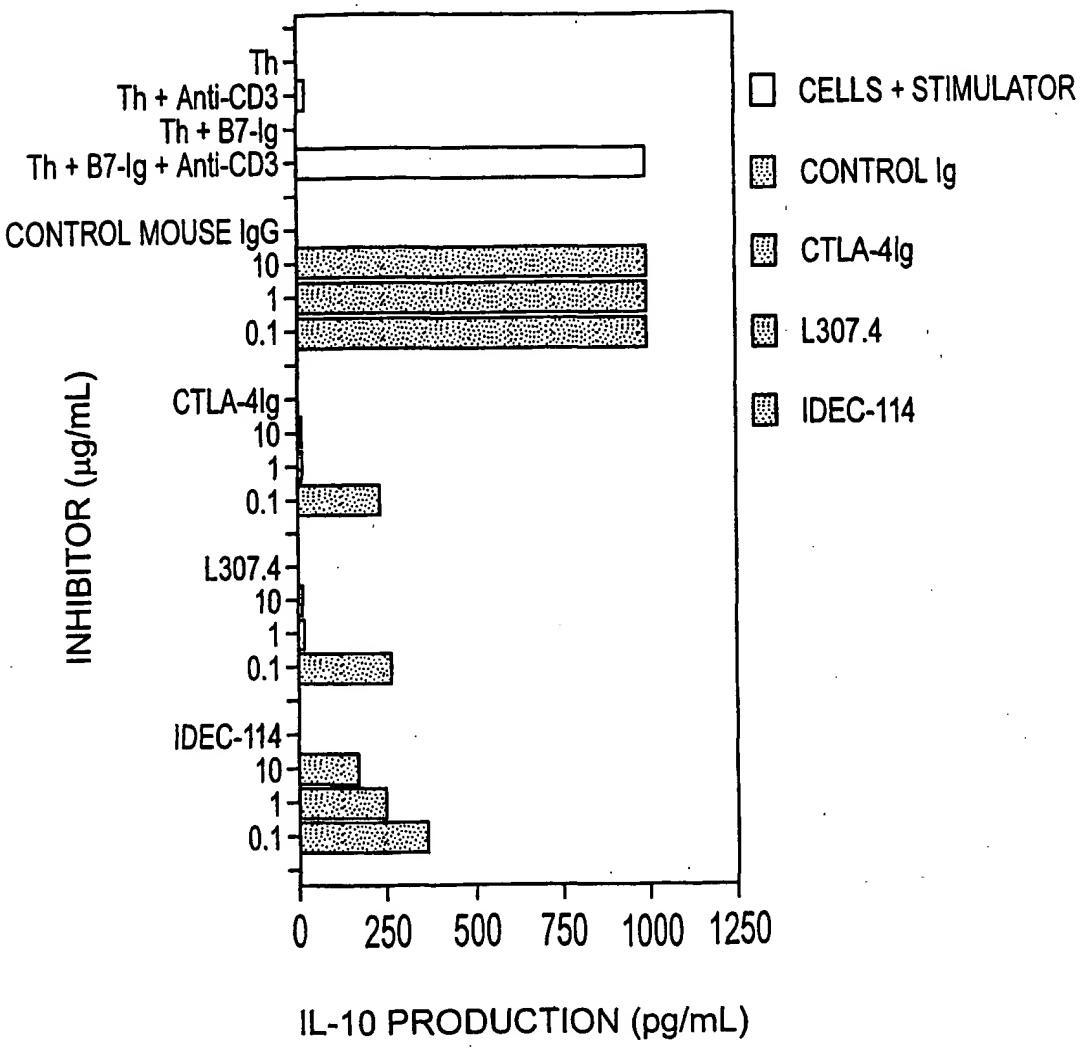



FIG. 13

IDEC-114 BLOCKS IL-2 PRODUCTION BY PURIFIED CD4+T CELLS WHEN LOW BEAD DESITIES OF B7 ARE USED AS STIMULATORS

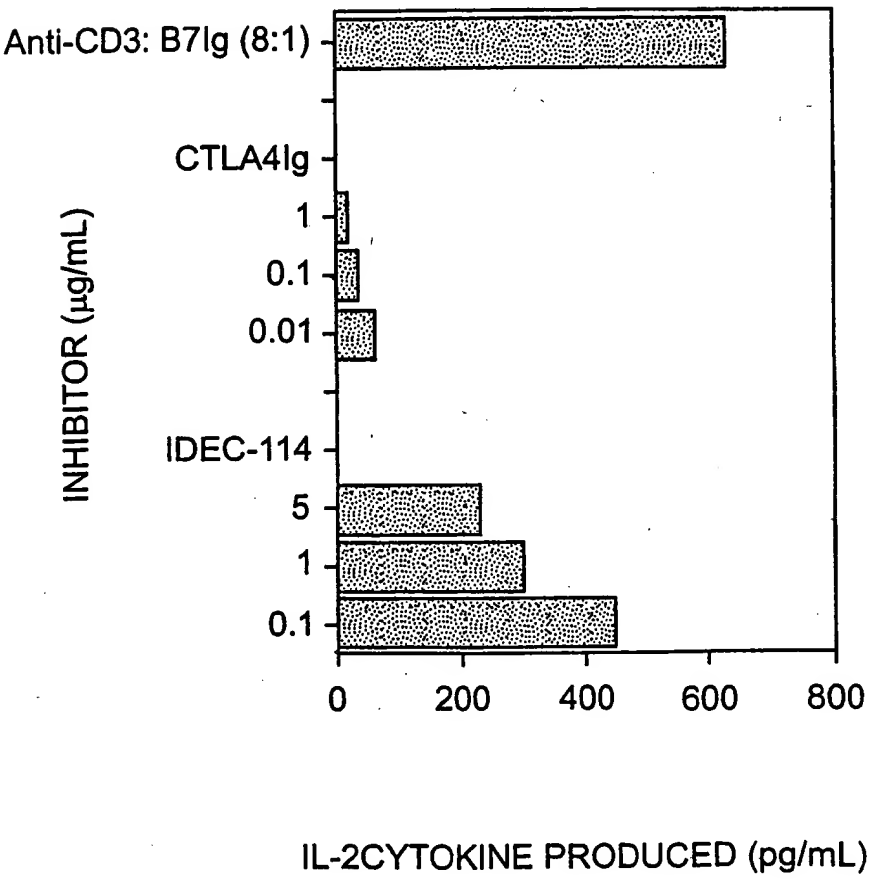



FIG. 14

# INTERNATIONAL SEARCH REPORT

Intern: application No.
PCT/US01/16364

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :A61K 39/395; C07K 16/28
US CL :Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 424/130.1, 133.1, 141.1, 143.1, 144.1, 153.1, 173.1; 530/387.1, 387.2, 388.1, 388.2, 388.22, 388.7, 388.73

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WEST, DIALOG, BIOSIS, EMBASE, CA, MEDLINE
search terms; b7.1, b7.1, antibod?, 16c10, 7c10, apoptosis

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | WO 98/19706 A (IDEC PHARMACEUTICALS COPORATION) 14 May 1998, see entire document. | 1-28 |
| Y | | 1-28 |

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

| | | | |
|---|---|---|---|
| * | Special categories of cited documents: | "T" | later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention |
| "A" | document defining the general state of the art which is not considered to be of particular relevance | "X" | document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone |
| "E" | earlier document published on or after the international filing date | "Y" | document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art |
| "L" | document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) | "&" | document member of the same patent family |
| "O" | document referring to an oral disclosure, use, exhibition or other means | | |
| "P" | document published prior to the international filing date but later than the priority date claimed | | |

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 16 JULY 2001 | 07 AUG 2001 |
| Name and mailing address of the ISA/US<br>Commissioner of Patents and Trademarks<br>Box PCT<br>Washington, D.C. 20231 | Authorized officer<br>PHILLIP GAMBEL |
| Facsimile No. (703) 305-3230 | Telephone No. (703) 308-0196 |

Form PCT/ISA/210 (second sheet) (July 1998)*

# INTERNATIONAL SEARCH REPORT

Intern pplication No.
PCT/US01/16364

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

424/130.1, 133.1, 141.1, 143.1, 144.1, 153.1, 173.1; 530/387.1, 387.3, 388.1, 388.2, 388.22, 388.7, 388.73

Form PCT/ISA/210 (extra sheet) (July 1998)★